



Standard Specification for Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX-AL-PEX) Pressure Pipe¹

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1. Scope

1.1 This specification covers a coextruded crosslinked polyethylene composite pressure pipe with a welded aluminum tube reinforcement between the inner and outer layers. The inner and outer crosslinked polyethylene layers are bonded to the aluminum tube by a melt adhesive. Included is a system of nomenclature for the crosslinked polyethylene-aluminum-crosslinked polyethylene (PEX-AL-PEX) pipes, the requirements and test methods for materials, the dimensions of the component layers and finished pipe, adhesion tests, and the burst and sustained pressure performance. Also given are the requirements and methods of marking. The pipe covered by this specification is intended for use in potable water distribution systems for residential and commercial applications, water service, underground irrigation systems, and radiant panel heating systems, baseboard, snow- and ice-melt systems, and gases that are compatible with the composite pipe and fittings.

1.2 This specification covers only composite pipes incorporating a welded aluminum tube. Pipes consisting of metallic layers not welded together are outside the scope of this specification.

1.3 Specifications for connectors for use with pipe meeting the requirements of this specification are given in Annex A1.

1.4 This specification excludes polyethylene-aluminum-polyethylene pipes (see Specification F 1282).

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 The following precautionary caveat pertains only to the test methods portion, Section 9, of this specification: *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:

¹ This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.11 on Composite.

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- D 618 Practice for Conditioning Plastics and for Testing²
- D 883 Terminology Relating to Plastics²
- D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure³
- D 1599 Test Method for Resistance to Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings³
- D 1600 Terminology for Abbreviated Terms Relating to Plastics²
- D 1898 Practice for Sampling of Plastics²
- D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings³
- D 2765 Test Methods for Determination of Gel Content and Swell Ratio of Crosslinked Ethylene Plastics⁴
- D 3350 Specification for Polyethylene Plastics Pipe and Fittings Materials⁴
- E 8 Test Methods for Tension Testing of Metallic Materials⁵
- F 412 Terminology Relating to Plastic Piping Systems³
- F 1282 Specification for Polyethylene/Aluminum/Polyethylene PE-AL-PE Composite Pressure Pipe³
- F 1974 Specification for Polyethylene/Aluminum/Polyethylene and Crosslinked Polyethylene/Aluminum/Crosslinked polyethylene Composite Pressure Pipe³
- 2.2 *National Sanitation Foundation Standard:*
 - Standard No. 61 Drinking Water System Components—Health Effects⁶
 - Standard No. 14 Plastics Piping System Components and Related Materials⁶
- 2.3 *Federal Standard:*
 - Fed. Std. No. 123 Marking for Shipments (Civil Agencies)⁷
- 2.4 *Military Standard:*
 - MIL-STD-129 Marking for Shipment and Storage⁷
- 2.5 *Uniform Classification Committee Standard:*
 - Uniform Freight Classification⁸
- 2.6 *National Motor Freight Traffic Association Standard:*

² Annual Book of ASTM Standards, Vol 08.01.

³ Annual Book of ASTM Standards, Vol 08.04.

⁴ Annual Book of ASTM Standards, Vol 08.02.

⁵ Annual Book of ASTM Standards, Vol 03.01.

⁶ Available from the NSF International, 789 Dixboro Rd., Ann Arbor, MI 48105.

⁷ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

⁸ Available from the Uniform Classification Committee, Suite 1106, 222 South Riverside Plaza, Chicago, IL 60606.

National Motor Freight Classification⁹

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *assembly*—the joint between a fitting and a length of pipe.

3.2.2 *PEX-AL-PEX pipe*—composite pipe produced by co-extrusion or extrusion of layers of polyethylene/aluminum/polyethylene bonded together with a melt adhesive and crosslinked by irradiation or chemical means in combination heat and moisture.

3.2.3 *pipe hoop stress*—for simplicity the value of the hoop stress quoted assumes a homogeneous wall. Local values of stress will vary with the different layers (see 3.2.3.1).

3.2.3.1 *Discussion*—Thick walled plastic pipes produced from one material have hoop stresses that vary through the wall, and are usually described by the Lamé Theory. The composite nature of the PEX-AL-PEX pipe, composed of materials with very different Young's Modulus values, will, on pressurization, not have a uniform stress distribution through the thickness of the wall of the pipe. The PEX-AL-PEX pipes have a hoop stress distribution that differs substantially from both the thick and thin walled pipe cases.

4. Pipe Classification

4.1 *Pipe Diameter*—The PEX-AL-PEX pipes are classified by the outside diameter.

4.2 *Pipe Dimension Ratio*—The concept of dimension ratio is not relevant to PEX-AL-PEX composite pipes, and cannot be used to relate pressure rating with total wall thickness.

5. Materials

5.1 *General*—The PEX-AL-PEX pipe is composed of one metallic layer, two layers of the same polymeric adhesive, and two layers of the same crosslinked polyethylene. For pipe made to this specification the constituent materials must meet the following requirements:

5.2 *Aluminum*—The aluminum shall have a thickness as specified in Table 1. The material shall have minimum elongations and ultimate tensile strengths of 20 % and 100 MPa (14 600 psi), respectively. The tests shall be conducted according to Test Methods E 8.

5.3 *Crosslinked Polyethylene:*

5.3.1 The polyethylene shall be, in the final finished state in the pipe, crosslinked as defined in Terminology D 883.

5.3.2 Polyethylene plastics used to make pipe meeting the requirements of this specification shall be virgin resin meeting the requirements of either Grade PE20A, B, or C; Grade PE23A, B, or C; Grade PE30A, B, or C; or Grade PE33A, B, or C in accordance with Specification D 3350.

5.3.3 Class B compounds shall have sufficient ultraviolet (UV) stabilizers to protect the pipe from deleterious effects due to continuous outdoor exposure during storage and shipping. Pipe produced from Class B compounds are not suitable for exposed outdoor application. Class A, B, and C compounds shall have sufficient antioxidants to meet the requirements in Specification D 3350.

5.4 *Melt Adhesive*—The material shall have a density cell of 1, 2, or 3; a melt index cell of 1, 2, or 3; and a color code of A or B, in accordance with Specification D 3350.

5.5 *Rework Material*—The use of reclaimed, recycled, or rework plastics is not permitted.

6. Requirements

6.1 *General*—The requirements and test methods in this specification cover PEX-AL-PEX pipes. Tests on the individual layers that comprise this composite pipe are outside the scope of this specification. The raw materials used, however, must conform to the requirements as set out in Section 5.

6.2 *Dimensions and Tolerances of Pipe:*

6.2.1 *Pipe Diameter*—The minimum outside diameter and tolerances of the pipe shall meet the requirements given in Table 1, when measured in accordance with 9.1 and 9.1.2. Maximum and minimum (out-of-roundness) tolerances apply only to measurements made on pipe prior to coiling.

6.2.2 *Pipe Wall Thickness*—The total pipe wall thickness shall meet the requirements given in Table 2, when measured in accordance with 9.1 and 9.1.3. The minimum wall thickness at any point of measurement of the pipe shall not be less than the value specified in Table 2.

6.2.3 *Outer Crosslinked Polyethylene Layer Thickness*—The thickness of the outer layer of crosslinked polyethylene in the PEX-AL-PEX pipe shall have a minimum value and tolerance as specified in Table 2, except for the polyethylene material overlaying the weld, which shall have a minimum

⁹ Available from the National Motor Freight Traffic Association, Inc., National Motor Freight Classification, American Trucking Associations, Inc., Traffic Dept., 1616 P St., NW, Washington, DC 20036.

TABLE 1 Outside Diameters, Aluminum Thickness, and Tolerances for PEX-AL-PEX

Nominal Pipe Size, mm (in.)	Minimum Outside Diameter, mm (in.)	Tolerance on Minimum, mm (in.)	Maximum Out-of-Roundness, ⁴ mm (in.)	Minimum Aluminum Thickness, mm (in.)	Tolerance on Thickness, mm (in.)
0912 (3/8)	12.00 (0.472)	+0.30 (0.012)	0.3 (0.012)	0.18 (0.007)	+0.09 (+0.0035)
1216 (1/2)	16.00 (0.630)	+0.30 (0.012)	0.4 (0.016)	0.18 (0.007)	+0.09 (+0.0035)
1620 (5/8)	20.00 (0.787)	+0.30 (0.012)	0.5 (0.020)	0.23 (0.009)	+0.09 (+0.0035)
2025 (3/4)	25.00 (0.984)	+0.30 (0.012)	0.5 (0.020)	0.23 (0.009)	+0.09 (+0.0035)
2532 (1)	32.00 (1.260)	+0.30 (0.012)	0.5 (0.020)	0.28 (0.011)	+0.09 (+0.0035)
3240 (1 1/4)	40.10 (1.579)	+0.30 (0.012)	0.5 (0.020)	0.33 (0.013)	
4150 (1 1/2)	50.10 (1.972)	+0.30 (0.012)	0.5 (0.020)	0.47 (0.018)	
5163 (2)	63.10 (2.484)	+0.40 (0.016)	0.5 (0.020)	0.57 (0.022)	
6075 (2 1/2)	75.10 (2.957)	+0.60 (0.024)	1.0 (0.039)	0.67 (0.026)	

⁴The out-of-roundness specification applies only to tubing prior to coiling.

TABLE 2 Wall Thickness for PEX-AL-PEX Composite Pipe

Nominal Pipe Size, mm (in.)	Total Wall Thickness, min, mm (in.)	Outer PE Layer Thickness, min, mm (in.)	Inner PE Layer Thickness, min, mm (in.)
0912 (3/8)	1.60 (0.063)	0.40 (0.016)	0.70 (0.028)
1216 (1/2)	1.65 (0.065)	0.40 (0.016)	0.90 (0.035)
1620 (5/8)	1.90 (0.075)	0.40 (0.016)	1.00 (0.039)
2025 (3/4)	2.25 (0.089)	0.40 (0.016)	1.10 (0.043)
2532 (1)	2.90 (0.114)	0.40 (0.016)	1.20 (0.047)
3240 (1 1/4)	3.85 (0.152)	0.40 (0.016)	1.70 (0.067)
4150 (1 1/2)	4.35 (0.171)	0.40 (0.016)	1.70 (0.067)
5163 (2)	5.80 (0.228)	0.40 (0.016)	2.05 (0.081)
6075 (2 1/2)	7.25 (0.285)	0.40 (0.016)	2.80 (0.110)

TABLE 3 Minimum Adhesive Force for PEX-AL-PEX Composite Pipe

Nominal Pipe Size, mm (in.)	Minimum Adhesive Force per 10-mm (0.394-in.) Pipe Strip, N (lbf)
3240 (1 1/4)	40 (9.0)
4150 (1 1/2)	50 (11.2)
5163 (2)	60 (13.5)
6075 (2 1/2)	70 (15.7)

thickness of half that specified in Table 2. The polyethylene thickness shall be measured in accordance with 9.2.

6.2.4 *Pipe Length*—The pipe shall be supplied coiled or in straight lengths as agreed upon with the purchaser and with an allowable tolerance of -0 mm (-0 in.).

6.3 *Adhesion Test:*

6.3.1 For Sizes 0912 (3/8) to 2532 (1) there shall be no delamination of the PEX and AL, either on the bore side or the outside (see Fig. 1). The test shall be conducted in accordance with 9.3.1.

6.3.2 The adhesion test of the PEX-layer to the aluminum for Sizes 3240 (1 1/4) to 6075 (2 1/2) is carried out by a separation test. The minimum adhesive force is specified in Table 3. The adhesive force shall not fall below these levels. The test shall be conducted in accordance with 9.3.2.

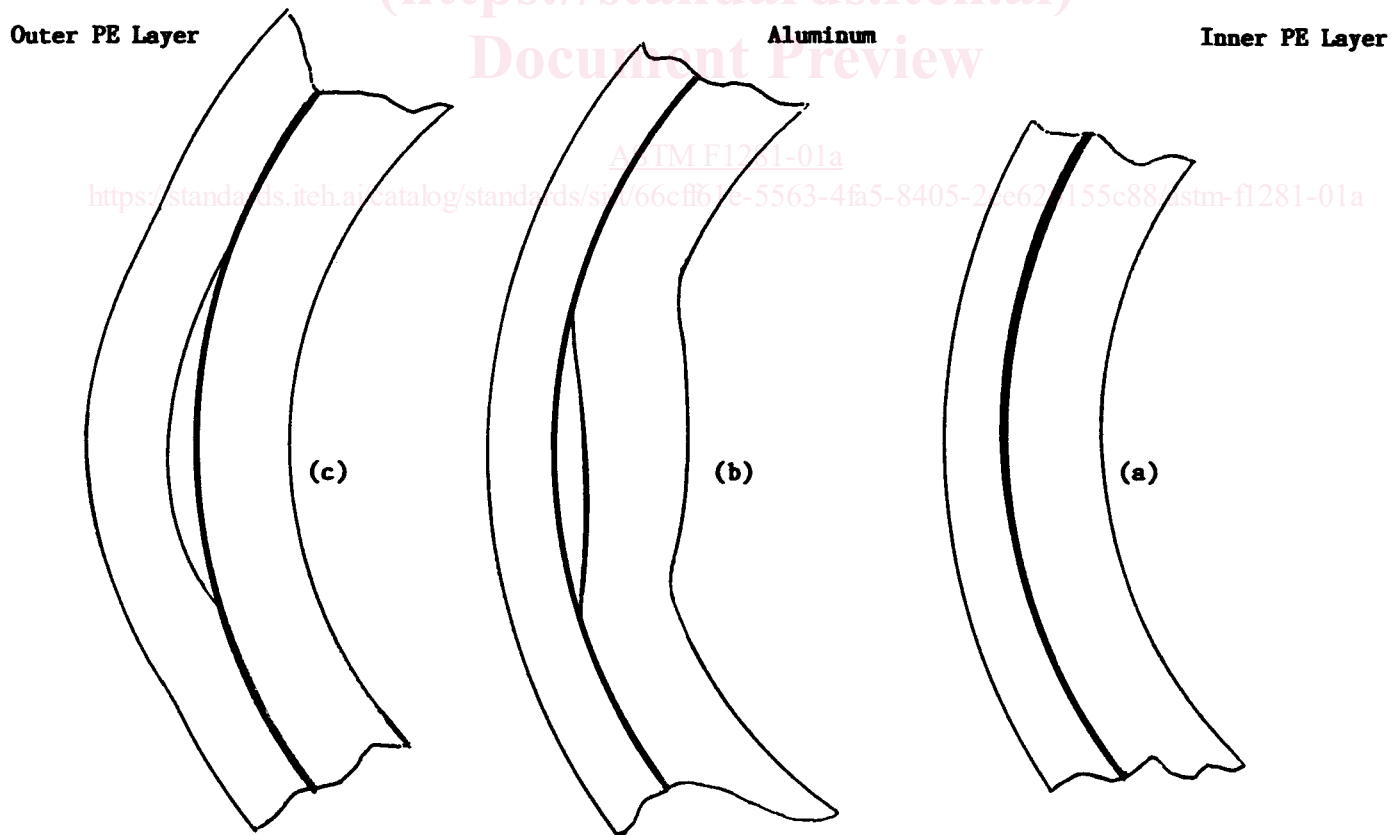
6.4 *Apparent Tensile Strength of Pipe*— The pipe rings, when tested in accordance with 9.4, shall meet the minimum strength specifications defined in Table 4.

6.5 *Burst Pressure*—The minimum burst pressure for PEX-AL-PEX pipe shall be as given in Table 4, when determined in accordance with 9.5.

6.6 *Sustained Pressure*—The PEX-AL-PEX pipe shall not fail, balloon, burst, or weep, as defined in Test Method D 1598, when tested for 10 h at the test pressure given in Table 5 at a temperature of 82°C (180°F) in accordance with 9.6.

6.7 *Gel Content*—When tested in accordance with 9.7, the gel content of the inner and outer tubes of crosslinked polyethylene shall have minimum values of either 65 % for the fully crosslinked silane material or 60 % for radiation crosslinked polyethylene. Test Methods D 2765 defines gel content (see Note 2).

NOTE 1—The gel test is one of several methods capable of indicating the degree of crosslinking. The different methods for assessing degree of



NOTE 1—(a) Good pipe showing no delamination, (b) Delamination between the inner layer and the aluminum, and (c) Delamination between the outer layer and the aluminum.

FIG. 1 Detection of Delamination

TABLE 4 Minimum Pipe Ring Strengths and 23°C (73.4°F) Burst Pressure of PEX-AL-PEX Composite Pipe

Nominal Pipe Size, mm (in.)	Minimum Pipe Ring Strength,	Minimum Pipe Ring Strength,	Minimum 23°C (73.4°F) Burst Pressure, kPa (psi)
	Type II PE, N(lb)	Type III PE, N(lb)	
0912 (3/8)	2000 (448)	2100 (470)	7000 (1020)
1216 (1/2)	2100 (470)	2300 (515)	6000 (880)
1620 (5/8)	2400 (538)	2500 (560)	5000 (730)
2025 (3/4)	2400 (538)	2500 (560)	4000 (580)
2532 (1)	2650 (598)	2500 (560)	4000 (580)
3240 (1 1/4)	3200 (719)	3500 (789)	4000 (580)
4150 (1 1/2)	3500 (789)	3700 (832)	3800 (554)
5163 (2)	5200 (1169)	5500 (1236)	3800 (554)
6075 (2 1/2)	6000 (1349)	6000 (1349)	3800 (554)

TABLE 5 Minimum Sustained Pressure for PEX-AL-PEX Composite Pipe

Nominal Pipe Size, mm (in.)	Minimum Sustained Pressure PEX-AL-PEX, kPa (psi)
0912 (3/8)	2720 (395)
1216 (1/2)	2720 (395)
1620 (5/8)	2720 (395)
2025 (3/4)	2720 (395)
2532 (1)	2720 (395)
3240 (1 1/4)	2000 (295)
4150 (1 1/2)	2000 (295)
5163 (2)	2000 (295)
6075 (2 1/2)	2000 (295)

crosslinking do not necessarily agree, so conformity to this specification requires degree of crosslinking to be determined in accordance with 9.7 only.

7. Workmanship

7.1 The pipe shall be free of visible cracks, holes, foreign inclusions, blisters, and other known injurious defects. The pipe shall be as uniform as practicable in color, opacity, density, and other physical properties.

8. Sampling and Conditioning

8.1 *Sampling*—Take a sample of the PEX-AL-PEX pipe sufficient to determine conformance with this specification. The number of specimens designated for each test shall be taken from pipe selected at random in accordance with the random sampling plan of Practice D 1898.

NOTE 2—Sample size and testing frequency of lots for quality control must be established by the manufacturer to ensure conformance to the specification. Sampling and frequency will vary with the specific circumstances.

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

8.3 *Conditioning*—Condition the specimens at $23 \pm 2^\circ\text{C}$ ($73.4 \pm 3.6^\circ\text{F}$) and $50 \pm 5\%$ relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required. In cases of disagreement, the tolerances shall be $\pm 1^\circ\text{C}$ ($\pm 1.8^\circ\text{F}$) and $\pm 2\%$ relative humidity.

8.4 *Test Conditions*—Conduct the test in the standard laboratory atmosphere of $23 \pm 2^\circ\text{C}$ ($73.4 \pm 3.6^\circ\text{F}$) and $50 \pm 5\%$ relative humidity, unless otherwise specified in the test methods or in this specification. In cases of disagreement, the tolerances shall be $\pm 1^\circ\text{C}$ (1.8°F) and $\pm 2\%$ relative humidity.

9. Test Methods

9.1 Dimensions and Tolerances:

9.1.1 *Pipe*—Any length of the PEX-AL-PEX composite pipe may be used to determine dimensions.

9.1.2 *Outside Diameter*—Measure the outside diameter of the PEX-AL-PEX pipe in accordance with Test Method D 2122.

9.1.3 *Wall Thickness*—Make micrometre measurements of the wall thickness in accordance with Test Method D 2122 to determine the maximum and minimum values. Measure the wall thickness at both ends of the pipe to the nearest 0.01 mm (0.0004 in.).

9.2 Outer Crosslinked Polyethylene Layer Thickness:

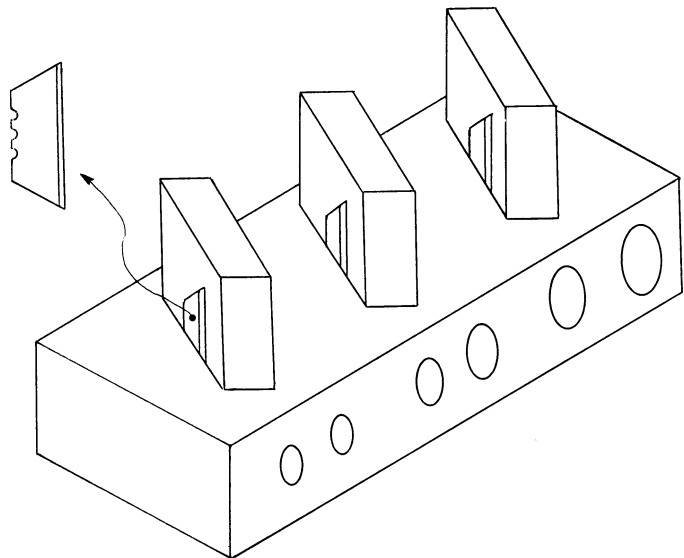
9.2.1 *Sample Preparation*—Cut the pipe with a sharp knife or other suitable cutter, ensuring that the pipe after cutting is not more than 10 % out-of-round.

9.2.2 *Thickness Determination*—Use a hand-held magnifying glass equipped with graduated reticule, or a laboratory microscope with graduated reticule. The reticule should measure to the nearest to 0.1 mm (0.004 in.). Determine the thickness of the outer layer of crosslinked polyethylene at six points around the circumference. One of the points only should be at the aluminum weld.

9.3 Adhesion Tests:

9.3.1 Visual Test:

9.3.1.1 *Cutting the Spiral*—Mount a Stanley 1991 or similarly sharp but rigid razor-like blade within a protective housing and angle to cut a $45 \pm 5^\circ$ spiral in the pipe (see Fig. 2). Choose a PEX-AL-PEX pipe at random and insert into the housing and rotate to form the spiral cut. The cut goes through the complete wall on one side of the pipe only. Run the spiral along the pipe for a minimum distance along the pipe axis equal to five times the outside diameter.


FIG. 2 Spiral Cutter for the Delamination Test