



Standard Specification for Polyethylene/Aluminum/Polyethylene (PE-AL-PE) Composite Pressure Pipe¹

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1. Scope

1.1 This specification covers a coextruded polyethylene composite pressure pipe with a welded aluminum tube reinforcement between the inner and outer layers. The inner and outer polyethylene layers are bonded to the aluminum tube by a melt adhesive. Included is a system of nomenclature for the polyethylene-aluminum-polyethylene (PE-AL-PE) pipes, the requirements and test methods for materials, the dimensions and strengths of the component tubes 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 composite pipe and fittings.

1.2 This specification relates only to metal and plastic composite pipes incorporating a welded metallic tube. The welded metallic tube of itself is capable of sustaining internal pressures. 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 crosslinked polyethylene-aluminum-crosslinked polyethylene pipes (see Specification F 1281).

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:

- D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing²
- D 1248 Specification for Polyethylene Plastics Molding and Extrusion Materials²
- D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure³
- D 1599 Test Method for 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 2104 Specification for Polyethylene (PE) Plastic Pipe, Schedule 40³
- D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings³
- D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials³
- D 3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter³
- 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 1281 Specification for Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX-AL-PEX) Pressure Pipe³
- F 1974 Specification for Metal Insert Fittings for Polyethylene/Aluminum/Polyethylene and Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene Composite Pressure Pipe³

2.2 NSF Standard:

- Standard No. 14 Plastics Piping System Components and Related Materials⁶
- Standard No. 61 Drinking Water System Components—Health Effects⁶

2.3 Uniform Classification Committee 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.

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Uniform Freight Classification⁷

2.4 *National Motor Freight Association Standard: National Motor Freight Classification*⁸

2.5 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)⁹

2.6 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage⁹

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 *pipe*—the complete structure, consisting of the aluminum, melt adhesive, and polyethylene layers intimately bonded together. The pipe for this specification is termed a PE-AL-PE composite pipe.

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 PE-AL-PE 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 PE-AL-PE 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 PE-AL-PE composite pipes are classified by outside diameter.

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

⁷ Available from the Uniform Classification Committee, Suite 1106, 222 South Riverside Plaza, Chicago, IL 60606.

⁸ Available from the National Motor Freight Traffic Association, Inc., National Motor Freight Classification, American Tracking Associations, Inc., Traffic Dept., 1616 P St., NW, Washington, DC 20036.

⁹ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

5. Materials

5.1 *General*—The PE-AL-PE pipe is composed of one metallic layer, two layers of the same polymeric adhesive and two layers of the same 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 *Polyethylene:*

5.3.1 Polyethylene plastics used to make pipe meeting the requirements of this specification are categorized by means of two criteria, namely, (1) short-term strength tests and (2) long-term strength tests.

5.3.2 This specification covers pipe made from PE plastics as defined by three hydrostatic design stresses developed on the basis of long-term tests (see Appendix X1).

5.3.3 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.

5.3.3.1 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 is not suitable for exposed outdoor application. Class A, B, and C compounds shall have sufficient antioxidants to meet the requirements in Specification D 3350.

5.3.3.2 Only polyethylene plastics meeting the requirement of Grade PE2406 as defined in Specification D 3350 shall be used to manufacture pipe rated at 82°C (180°F). The PE2406 shall be an ethylene-octene copolymer having a PPI listing for 82°C (180°F).

5.3.4 The polyethylene compound used shall meet the minimum 80°C (176°F) temperature stress rupture lifetimes for pipe as specified in Specifications D 2104 and D 3035.

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*—Clean rework material, generated from the manufacturer's own production, may be used by the same manufacturer, as long as the pipe produced meets all of

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

Nominal Pipe Size, mm (in.)	Minimum Outside Diameter, mm (in.)	Tolerance on Minimum, mm (in.)	Maximum Out-of-Roundness, ^A 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 (0.014)	
4150 (1 1/2)	50.10 (1.972)	+0.30 (0.012)	0.5 (0.020)	0.47 (0.020)	
5163 (2)	63.10 (2.484)	+0.40 (0.016)	0.5 (0.020)	0.57 (0.024)	
6075 (2 1/2)	75.10 (2.957)	+0.60 (0.024)	1.0 (0.039)	0.67 (0.028)	

^AThe out-of-roundness specification applies only to tubing prior to coiling.

the requirements of this specification. Rework material containing aluminum or reprocessed or recycled plastics shall not be used for the production of pipe.

6. Requirements

6.1 *General*—The requirements and test methods in this specification cover PE-AL-PE 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 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 minimum wall thickness specified in Table 2.

6.2.3 *Outer Polyethylene Layer Thickness*—The thickness of the outer layer of polyethylene in the PE-AL-PE 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 thickness of half that specified in Table 2. The polyethylene thickness is 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 with an allowable tolerance of -0 mm.

6.3 Adhesion Test:

6.3.1 For Sizes 0912 ($\frac{3}{8}$) to 2532 (1) there shall be no delamination of the PE 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 PE-layer to the aluminum for Sizes 3240 ($1\frac{1}{4}$) to 6075 ($2\frac{1}{2}$) 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 as specified in Table 4.

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

TABLE 2 Wall Thickness for PE-AL-PE 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 ($\frac{3}{8}$)	1.60 (0.063)	0.40 (0.016)	0.70 (0.028)
1216 ($\frac{1}{2}$)	1.65 (0.065)	0.40 (0.016)	0.90 (0.035)
1620 ($\frac{5}{8}$)	1.90 (0.075)	0.40 (0.016)	1.00 (0.039)
2025 ($\frac{3}{4}$)	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 ($1\frac{1}{4}$)	3.85 (0.152)	0.40 (0.016)	1.70 (0.067)
4150 ($1\frac{1}{2}$)	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 ($2\frac{1}{2}$)	7.25 (0.285)	0.40 (0.016)	2.80 (0.110)

6.6 Sustained Pressure—

6.6.1 PE-AL-PE pipe rated at 60°C (140°F) shall not fail, ballon, burst, or weep as defined in Test Method D 1598 when tested in accordance with 9.6 for 10h at the test pressure given in Table 5 at a temperature of 60°C (140°F).

6.6.2 PE-AL-PE pipe rated at 82°C (180°F) shall not fail, ballon, burst, or weep as defined in Test Method D 1598 when tested in accordance with 9.6 for 10 h at the test pressure given in Table 5 at a temperature of 82°C (180°F).

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 commercially practicable in color, opacity, and regularity of the distribution of the polyethylene inside and outside.

8. Sampling and Conditioning

8.1 *Sampling*—Take a sample of the PE-AL-PE 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 1—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 ± 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 ± 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 ± 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 ± 2 % relative humidity.

9. Test Methods

9.1 Dimensions and Tolerances:

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

9.1.2 *Outside Diameter*—Measure the outside diameter of the PE-AL-PE 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.).

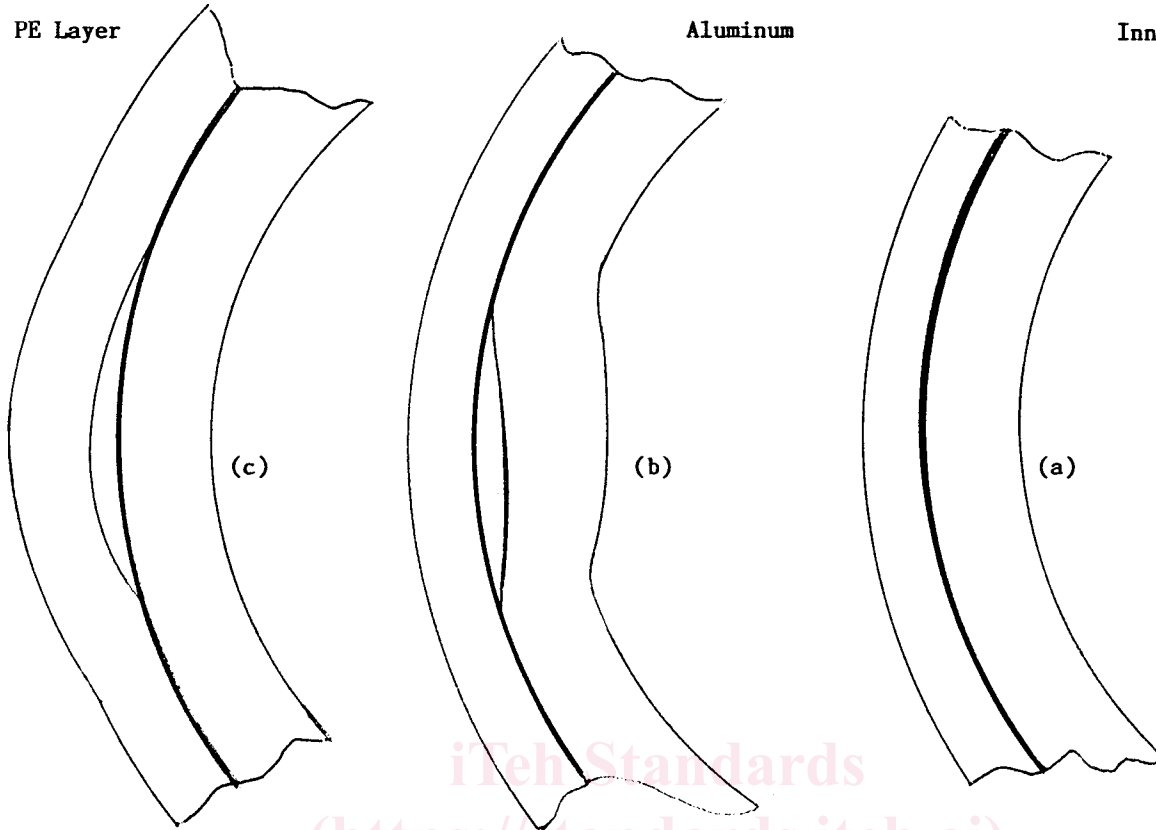
9.2 Outer Polyethylene Layer Thickness:

9.2.1 *Sample Preparation*—Select the sample of pipe at random. Cut the pipe with a sharp knife or other suitable cutter,

Outer PE Layer

Aluminum

Inner PE Layer



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 3 Minimum Adhesive Force for PE-AL-PE Composite Pipe

Nominal Pipe Size, mm (in.)	Minimum Adhesive Force per 10-mm (0.394-in.) Pipe Strip, N (lbf)
3240 (1¼)	40 (9.0)
4150 (1½)	50 (11.2)
5163 (2)	60 (13.5)
6075 (2½)	70 (15.7)

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

Nominal Pipe Size, mm (in.)	Minimum Sustained Pressure PE-AL-PE, kPa (psi)
0912 (¾)	2720 (395)
1216 (½)	2720 (395)
1620 (5/8)	2720 (395)
2025 (¾)	2720 (395)
2532 (1)	2720 (395)
3240 (1¼)	2100 (305)
4150 (1½)	2100 (305)
5163 (2)	2100 (305)
6075 (2½)	2100 (305)

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

Nominal Pipe Size, mm (in.)	Minimum Pipe Ring Strength, Type II PE, N (lb)	Minimum Pipe Ring Strength, Type III PE, N (lb)	Minimum 23°C (73.4°F) Burst Pressure, kPa (psi)
0912 (¾)	2000 (448)	2100 (470)	7000 (1020)
1216 (½)	2100 (470)	2300 (515)	6000 (880)
1620 (5/8)	2400 (538)	2500 (560)	5000 (730)
2025 (¾)	2400 (538)	2500 (560)	4000 (580)
2532 (1)	2650 (598)	2500 (560)	4000 (580)
3240 (1¼)	3200 (719)	3500 (789)	4000 (580)
4150 (1½)	3500 (789)	3700 (832)	3800 (554)
5163 (2)	5200 (1169)	5500 (1236)	3800 (554)
6075 (2½)	6000 (1349)	6000 (1349)	3800 (554)

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 0.1 mm (0.004 in.). Determine the thickness

of the outer coating of polyethylene at six points around the circumference. Only one of the points should be at the aluminum weld.

9.3 *Adhesion Test:*

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.

9.3.1.2 *Examining for Delamination*—Firmly hold the pipe with the spiral cut at the uncut end and create a ribbon of pipe