Designation: ~~F1282 – 23~~ F1282 – 23a

An American National Standard

Standard Specification for Polyethylene/Aluminum/Polyethylene (PE-AL-PE) Composite Pressure Pipe[1]

This standard is issued under the fixed designation F1282; 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 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 radient 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 composite pipes incorporating a welded aluminum tube having both internal and external polyethylene layers. The welded aluminium tube is capable of sustaining internal pressures. Pipes consisting of metallic layers not welded together and plastic layers other than polyethylene 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 F1281).

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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]

[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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[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.

***A Summary of Changes section appears at the end of this standard**

D618 Practice for Conditioning Plastics for Testing
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
D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
E8/E8M Test Methods for Tension Testing of Metallic Materials
F412 Terminology Relating to Plastic Piping Systems
F1281 Specification for Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX-AL-PEX) Pressure Pipe
F1974 Specification for Metal Insert Fittings for Polyethylene/Aluminum/Polyethylene and Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene Composite Pressure Pipe

2.2 *NSF Standard:*
Standard No. 14 Plastics Piping System Components and Related Materials[3]
Standard No. 61 Drinking Water System Components—Health Effects[3]

2.3 *Uniform Classification Committee Standard:*
Uniform Freight Classification[4]

2.4 *National Motor Freight Association Standard:*
National Motor Freight Classification[5]

2.5 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[6]

2.6 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage[6]

2.7 *PPI Publication:*[7]
PPI TR-3 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) Ratings, and Categorized Required Strength (CRS) for Thermoplastic Piping Materials or Pipe

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, 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 Lame 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.

[3] Available from the NSF International, N. 789 Dixboro Rd., Ann Arbor, MI 48113-0140.
[4] Available from the Uniform Classification Committee, Suite 1106, 222 South Riverside Plaza, Chicago, IL 60606.
[5] 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.
[6] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.
[7] Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org.

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

Nominal Pipe Size	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.)
09	12.00 (0.472)	+0.30 (0.012)	0.3 (0.012)	0.18 (0.007)	+0.09 (+0.0035)
12	16.00 (0.630)	+0.30 (0.012)	0.4 (0.016)	0.18 (0.007)	+0.09 (+0.0035)
16	20.00 (0.787)	+0.30 (0.012)	0.5 (0.020)	0.23 (0.009)	+0.09 (+0.0035)
20	25.00 (0.984)	+0.30 (0.012)	0.5 (0.020)	0.23 (0.009)	+0.09 (+0.0035)
25	32.00 (1.260)	+0.30 (0.012)	0.5 (0.020)	0.28 (0.011)	+0.09 (+0.0035)
32	40.10 (1.579)	+0.30 (0.012)	0.5 (0.020)	0.33 (0.014)	
41	50.10 (1.972)	+0.30 (0.012)	0.5 (0.020)	0.47 (0.020)	
51	63.10 (2.484)	+0.40 (0.016)	0.5 (0.020)	0.57 (0.024)	
60	75.10 (2.957)	+0.60 (0.024)	1.0 (0.039)	0.67 (0.028)	

[A] The out-of-roundness specification applies only to tubing prior to coiling.

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.

5. Materials

5.1 *General*—The PE-AL-PE pipe is composed of one metallic layer, two layers of the same polyethylene melt 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),~~ (14 600 psi), respectively. The tests shall be conducted according to Test Methods E8/E8M.

5.3 *Polyethylene:*

5.3.1 Polyethylene resin used to make pipe meeting the requirements of this specification shall be virgin resin having a material designation Code of PE2708, PE4708 or PE4710.

5.3.1.1 The inner PE compound shall meet the color and UV stabilizer code of A, B, C, D or E in accordance with Specification D3350. The outer layer PE compound shall meet the color and UV stabilizer code of E in accordance with Specification D3350.

5.3.1.2 Only polyethylene plastics having an established HDB at 82°C (180°F) in accordance with PPI TR 3 shall be used to manufacture pipe rated at 82°C (180°F).

5.4 *Polyethylene Melt Adhesive*—The polyethylene melt adhesive 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 D3350.

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 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.

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

Nominal Pipe Size	Total Wall Thickness, min, mm (in.)	Wall Tolerance (+) mm	Outer PE Layer Thickness, min, mm (in.)	Inner PE Layer Thickness, min, mm (in.)
09	1.60 (0.063)	0.40 (0.016)	0.40 (0.016)	0.70 (0.028)
12	1.65 (0.065)	0.40 (0.016)	0.40 (0.016)	0.90 (0.035)
16	1.90 (0.075)	0.40 (0.016)	0.40 (0.016)	1.00 (0.039)
20	2.25 (0.089)	0.50 (0.020)	0.40 (0.016)	1.10 (0.043)
25	2.90 (0.114)	0.60 (0.024)	0.40 (0.016)	1.20 (0.047)
32	3.85 (0.152)	0.60 (0.024)	0.40 (0.016)	1.70 (0.067)
41	4.35 (0.171)	0.60 (0.024)	0.40 (0.016)	1.70 (0.067)
51	5.80 (0.228)	0.60 (0.024)	0.40 (0.016)	2.05 (0.081)
60	7.25 (0.285)	0.60 (0.024)	0.40 (0.016)	2.80 (0.110)

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 09 to 25 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 32 to 60 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.

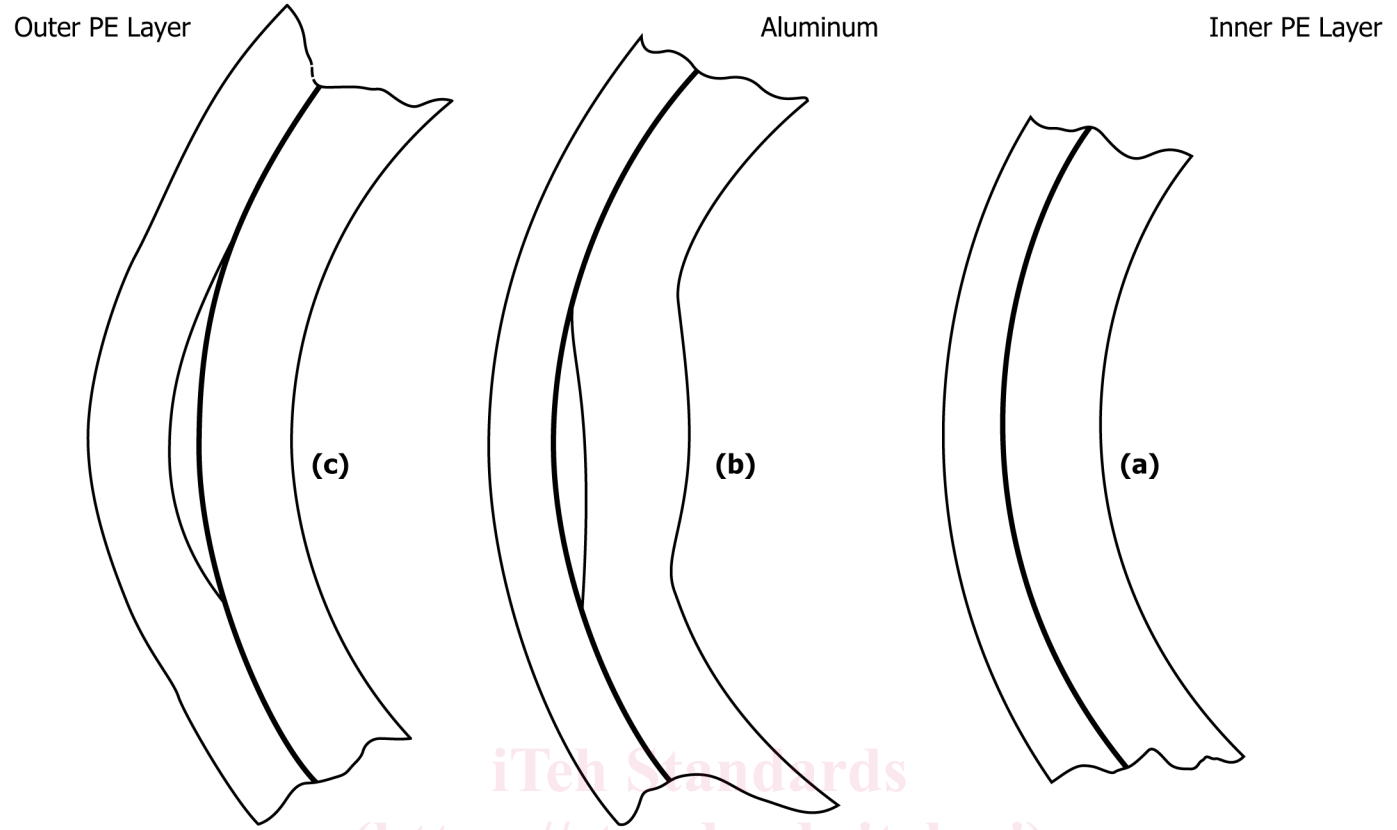
6.5 *Minimum Burst Pressure*—The minimum burst pressure for PE-AL-PE pipe shall be as given in Table 4, when determined in accordance with 9.5.

6.6 *Sustained Pressure:*

6.6.1 The PE-AL-PE pipe rated at ~~60°C (140°F)~~ 60 °C (140 °F) shall not fail, balloon, burst, or weep, as defined in Test Method D1598, when tested for 10 h at the test pressure given in Table 5 at a temperature of ~~60°C (140°F)~~60 °C (140 °F) in accordance with 9.6.

6.6.2 PE-AL-PE pipe rated at ~~82°C (180°F)~~ 82 °C (180 °F) shall not fail, balloon, burst, or weep as definded in Test Method D1598 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).~~82 °C (180 °F).

6.7 *Pressure design basis (PDB)*—All pipe meeting the requirements of this specification shall have a PDB of 400 psi at ~~73°F~~73 °F and 200 psi at ~~140°F~~140 °F obtained by categorizing the long-term hydrostatic pressure strength determined in accordance with Test Method D2837 and PPI TR-3. PDB is specific to the particular wall construction and pipe diameter.



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	Minimum Adhesive Force per 10-mm (0.394-in.) Pipe Strip, N (lbf)
32	40 (9.0)
41	50 (11.2)
51	60 (13.5)
60	70 (15.7)

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

Nominal Pipe Size	Minimum Pipe Ring Strength, Type II PE, N (lb)	Minimum Pipe Ring Strength, Type III PE, N (lb)	Minimum ~~23°C (73.4°F)~~23 °C (73.4 °F) Burst Pressure, kPa (psi)
09	2000 (448)	2100 (470)	7000 (1020)
12	2100 (470)	2300 (515)	6000 (880)
16	2400 (538)	2500 (560)	5000 (730)
20	2400 (538)	2500 (560)	4000 (580)
25	2650 (598)	2500 (560)	4000 (580)
32	3200 (719)	3500 (789)	4000 (580)
41	3500 (789)	3700 (832)	3800 (554)
51	5200 (1169)	5500 (1236)	3800 (554)
60	6000 (1349)	6000 (1349)	3800 (554)

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.

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

Nominal Pipe Size	Minimum Sustained Pressure PE-AL-PE, kPa (psi) at ~~60°C (140°F)~~60 °C (140 °F)	Minimum Sustained Pressure PE-AL-PE, kPa (psi) at ~~82°C (180°F)~~82 °C (180 °F)
09	2480 (360)	2340 (340)
12	2480 (360)	2340 (340)
16	2480 (360)	2340 (340)
20	2480 (360)	2340 (340)
25	2480 (360)	2340 (340)
32	2100 (305)	...
41	2100 (305)	...
51	2100 (305)	...
60	2100 (305)	...

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.

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 ± 2°C (73.4 ± 3.6°F) and 50~~23 °C ± 2 °C (73.4 °F ± 3.6 °F) and 50 % ± 10 % relative humidity for not less than 40 h prior to test 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 (±1.8°F)~~±1 °C (±1.8 °F) and ±2 % relative humidity.

8.4 *Test Conditions*—Conduct the test in the standard laboratory atmosphere of ~~23 ± 2°C (73.4 ± 3.6°F) and 50~~23 °C ± 2 °C (73.4 °F ± 3.6 °F) and 50 % ± 10 % relative humidity, unless otherwise specified in the test methods or in this specification. In cases of disagreement, the tolerances shall be ~~±1°C (1.8°F)~~±1 °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 D2122.

9.1.3 *Wall Thickness*—Make micrometre measurements of the wall thickness in accordance with Test Method D2122 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, 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:*

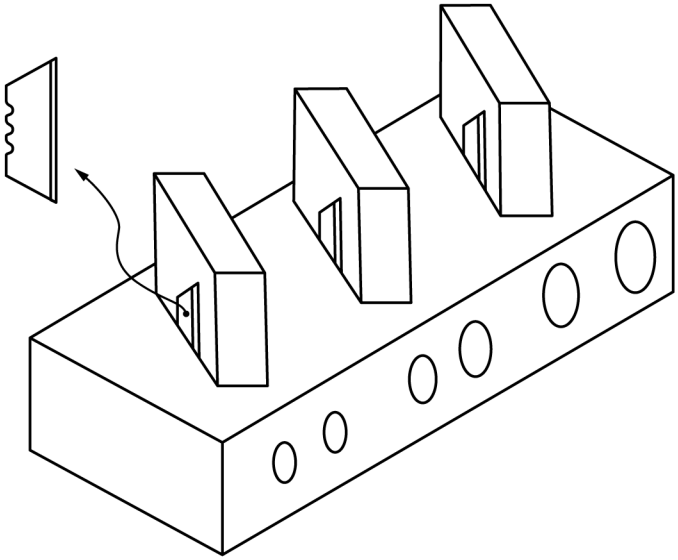


FIG. 2 Spiral Cutter for the Delamination Test

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 ± 5°~~ 45° ±5° 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 material by opening out the spiral-cut pipe. Pliers can be used to grip the spiral-cut pipe. Examine the wall of the pipe visually side-on for evidence of delamination between the metal and plastic layers (see Fig. 1).

9.3.2 *Separation Test:*

9.3.2.1 *Specimen*—Five pipe sections of 10-mm (0.394-in.) length are cut at random intervals. The outer layers of the pipe (outer PE-layer together with the aluminum) are separated mechanically from the inner PE-layer with an appropriate device on the opposite side to the welding seam. The outer layers are separated on one side to about 5 mm from the pipe in order to allow clamping. The adhesion for the outer PE-layer to the aluminum is then visually examined for delamination at the corresponding test sample.

9.3.2.2 *Test Equipment:*

(1) Tension Testing Device, with suitable pull-off device (see Fig. 3).
(2) D_{roller} = 95 % of the required pipe inner diameter.
(3) d_i = pipe inner diameter.

9.3.2.3 *Test Procedure*—Remove the outer layers from the pipe at ~~23 ± 2°C (73.4 ± 3.6°F)~~ 23 °C ± 2 °C (73.4 °F ± 3.6 °F) with a linear speed of 50 mm/min (≈2 in./min). Record the force diagram.

9.4 *Ring Test:*

9.4.1 *Sample Size and Shape*—Cut rings of the PE-AL-PE pipe so that the two sides are parallel and at ~~90 ± 2°~~ 90° ±2° to the pipe axis. The length of each ring shall be ~~25~~25 mm ± 1 mm ~~(1~~(1 in. ± 0.04 in.). Cut a minimum of 15 samples consecutively along the axis of the pipe.

9.4.2 *Ring Tests*—Test the 15 consecutively cut samples using a tensile testing machine. Arrange the rings so that the aluminum weld is at 90° to the tensile axis as shown in Fig. 4. The crosshead speed shall be 50 mm/min ± 2.5 mm/min (2 in./min ± 0.1 in./min). Mount the rings of pipe on two steel rods of minimum diameter of 4 mm ~~(0.16 in.).~~ (0.16 in.). Record the peak force.

9.5 *Burst Pressure:*