Designation: F3506 – 21ε1

An American National Standard

Standard Specification for Polyethylene of Raised Temperature/Aluminum/Polyethylene of Raised Temperature (PE-RT/AL/PE-RT) Composite Pressure Pipe based on Inner Diameter (ID) for use in Air Conditioning and Refrigeration Line Set Systems[1]

This standard is issued under the fixed designation F3506; 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.

ε[1] NOTE—Table A2.1 was editorially corrected in April 2021.

1. Scope

1.1 This specification covers a coextruded polyethylene composite pressure pipe with a butt 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 of raised temperature (PE-RT/AL/PE-RT) 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 air conditioning and refrigeration (ACR) line set systems.

1.2 This specification relates only to composite pipes incorporating a butt welded aluminum tube having both internal and external polyethylene layers. The welded aluminum tube is capable of sustaining internal pressures. Pipes consisting of metallic layers not butt welded together and plastic layers other than polyethylene are outside the scope of this specification.

1.3 The dimensions in this specification are ID controlled to match that of ACR Copper Tube so that the flowrate and volume remains the same on a size-for-size basis.

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

1.5 This specification excludes crosslinked polyethylene-aluminum-crosslinked polyethylene pipes (see Specification F1281).

1.6 This specification tests the pipe for service at 60 °C ± 2 °C (140 °F ± 3 °F) or 82 °C ± 2 °C (180 °F ± 3 °F).

1.7 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.8 *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.*

1.9 *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]

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

D3895 Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry

[1] This test method 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.

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

2.2 *ASHRAE Standard:*[3]
ASHRAE Standard 15 Safety Standard for Refrigeration Systems

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

2.4 *National Motor Freight Association Standard:*[4]
National Motor Freight Classification

2.5 *Federal Standard:*[5]
Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

2.6 *Underwriters Laboratory Standards:*[6]
UL 207 Refrigerant-Containing Components and Accessories
UL 1963 Refrigerant Recovery/Recycling Equipment

2.7 *Military Standard:*[5]
MIL-STD-129 Marking for Shipment and Storage

2.8 *PPI Standards:*[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
PPI TR-4 PPI Listing of Hydrostatic Design Basis (HDB), Hydrostatic Design Stress (HDS), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings For Thermoplastic Piping Materials or Pipe

[3] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.
[4] Available from National Motor Freight Traffic Association, Inc. (NMFTA), 1001 N. Fairfax St., Suite 600, Alexandria, VA 22314-1798, http://www.nmfta.org.
[5] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.
[6] Available from Underwriters Laboratories (UL), UL Headquarters, 333 Pfingsten Road, Northbrook, IL, 60062, http://www.ul.com.
[7] Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org.

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, n*—a system made up of pipe, fittings, flanges, valves, or other piping components.

4. Pipe Classification

4.1 *Pipe Diameter*—The PE-RT/AL/PE-RT composite pipes are classified by inside diameter.

NOTE 1—*Pipe Dimension Ratio*—The concept of dimension ratio is not relevant to PE-RT/AL/PE-RT laminated pipes, and cannot be used to relate pressure rating with total wall thickness.

5. Materials

5.1 *General*—The PE-RT/AL/PE-RT 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 11 % and 124 MPa (18000 psi), respectively when tested in accordance with 9.5.

5.3 *PE-RT:*

5.3.1 PE-RT resin used to make pipe meeting the requirements of this specification shall be virgin resin, reworked plastic, or both, and shall have a Plastic Pipe Institute (PPI) HDB established at 23 °C (73 °F) and 82 °C (180 °F).

5.3.1.1 Only PE-RT plastics having an HDB at 82 °C (180 °F) shall be used to manufacture pipe rated at 82 °C (180 °F).

5.3.1.2 The inner PE-RT 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-RT compound shall meet the color and UV stabilizer code C or E in accordance with Specification D3350. Black Code C compound shall contain a minimum of 2 % well-dispersed carbon black. Color Code E compound shall contain sufficient UV stabilization to provide extended long-term resistance to UV degradation or color fade from direct sunlight exposure.

NOTE 2—HVAC equipment in locations such as outdoor rooftop

TABLE 1 Inside Diameters, Aluminum Thickness, and Tolerances for PE-RT/AL/PE-RT

Nominal Pipe Size	Minimum Inside Diameter, mm (in.)	Tolerance on Minimum, mm (in.)	Maximum Out-of Roundness,[A] mm (in.)	Minimum Aluminum Thickness, mm (in.)	Tolerance on Aluminum Thickness, mm (in.)
¼	4.83 (0.190)	+0.30 (0.012)	0.40 (0.016)	0.36 (0.014)	+0.09 (+0.004)
⅜	7.90 (0.311)	+0.30 (0.012)	0.40 (0.016)	0.36 (0.014)	+0.09 (+0.004)
½	11.07 (0.436)	+0.30 (0.012)	0.50 (0.020)	0.51 (0.020)	+0.09 (+0.004)
⅝	14.10 (0.555)	+0.30 (0.012)	0.50 (0.020)	0.70 (0.028)	+0.09 (+0.004)
¾	17.27 (0.680)	+0.30 (0.012)	0.50 (0.020)	0.85 (0.033)	+0.09 (+0.004)
⅞	19.94 (0.785)	+0.30 (0.012)	0.50 (0.020)	0.95 (0.037)	+0.09 (+0.004)
1⅛	26.04 (1.025)	+0.30 (0.012)	0.50 (0.020)	1.20 (0.047)	+0.09 (+0.004)

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

installations can expose uncovered refrigerant lines to direct UV radiation from sunlight. Code E color outer layer refrigerant lines are susceptible to UV degradation if subject to long term UV exposure. Installation practices such as insulation and shielding over refrigerant lines are recommended to provide protection against UV degradation.

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.

6. Requirements

6.1 *General*—The requirements and test methods in this specification cover PE-RT/AL/PE-RT 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 inside 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 *Polyethylene Layer Thickness*—The thickness of the inner and outer layers of polyethylene in the PE-RT/AL/PE-RT pipe shall have a minimum value and tolerance as 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 There shall be no delamination of the PE-RT and AL, either on the bore side or the outside (see Fig. 1). The test shall be conducted in accordance with 9.3.1.

6.4 *Apparent Tensile Strength of Pipe*—The pipe rings, when tested in accordance with 9.4, shall meet the minimum strength as specified in Table 3.

6.5 *Minimum Burst Pressure*—The minimum burst pressure for PE-RT/AL/PE-RT pipe shall be as given in Table 3, when determined in accordance with 9.6.

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

Nominal Pipe Size	Total Wall Thickness, min, mm (in.)	Wall Tolerance (+) mm (in.)	Outer PE-RT Layer Thickness, min, mm (in.)	Inner PE-RT Layer Thickness, min, mm (in.)
¼	1.92 (0.076)	0.40 (0.016)	0.40 (0.016)	1.00 (0.039)
⅜	1.92 (0.076)	0.40 (0.016)	0.40 (0.016)	1.00 (0.039)
½	2.27 (0.089)	0.40 (0.016)	0.40 (0.016)	1.20 (0.047)
⅝	2.56 (0.101)	0.40 (0.016)	0.40 (0.016)	1.30 (0.051)
¾	2.81 (0.111)	0.50 (0.020)	0.40 (0.016)	1.40 (0.055)
⅞	2.91 (0.115)	0.50 (0.020)	0.40 (0.016)	1.40 (0.055)
1⅛	3.36 (0.132)	0.60 (0.024)	0.40 (0.016)	1.60 (0.063)

6.6 *Sustained Pressure:*

6.6.1 The PE-RT/AL/PE-RT pipe rated at 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 4 at a temperature of 60 °C (140 °F) in accordance with 9.7.

6.6.2 PE-RT/AL/PE-RT pipe rated at 82 °C (180 °F) shall not fail, balloon, burst, or weep as defined in Test Method D1598 when tested in accordance with 9.7 for 10 h at the test pressure given in Table 4 at a temperature of 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 23 °C (73 °F) and 200 psi at 82 °C (180 °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.

6.8 *Refrigerant Exposure*—All pipe designed to be used with refrigerant shall be tested in accordance with 9.8 for compatibility with each refrigerant as specified by the manufacturer.

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-RT/AL/PE-RT 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 3—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 °C ± 2 °C (73 °F ± 3 °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) and ±2 % relative humidity.

8.4 *Test Conditions*—Conduct the test in the standard laboratory atmosphere of 23 °C ± 2 °C (73 °F ± 3 °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 (2 °F) and ±2 % relative humidity.

9. Test Methods

9.1 *Dimensions and Tolerances:*

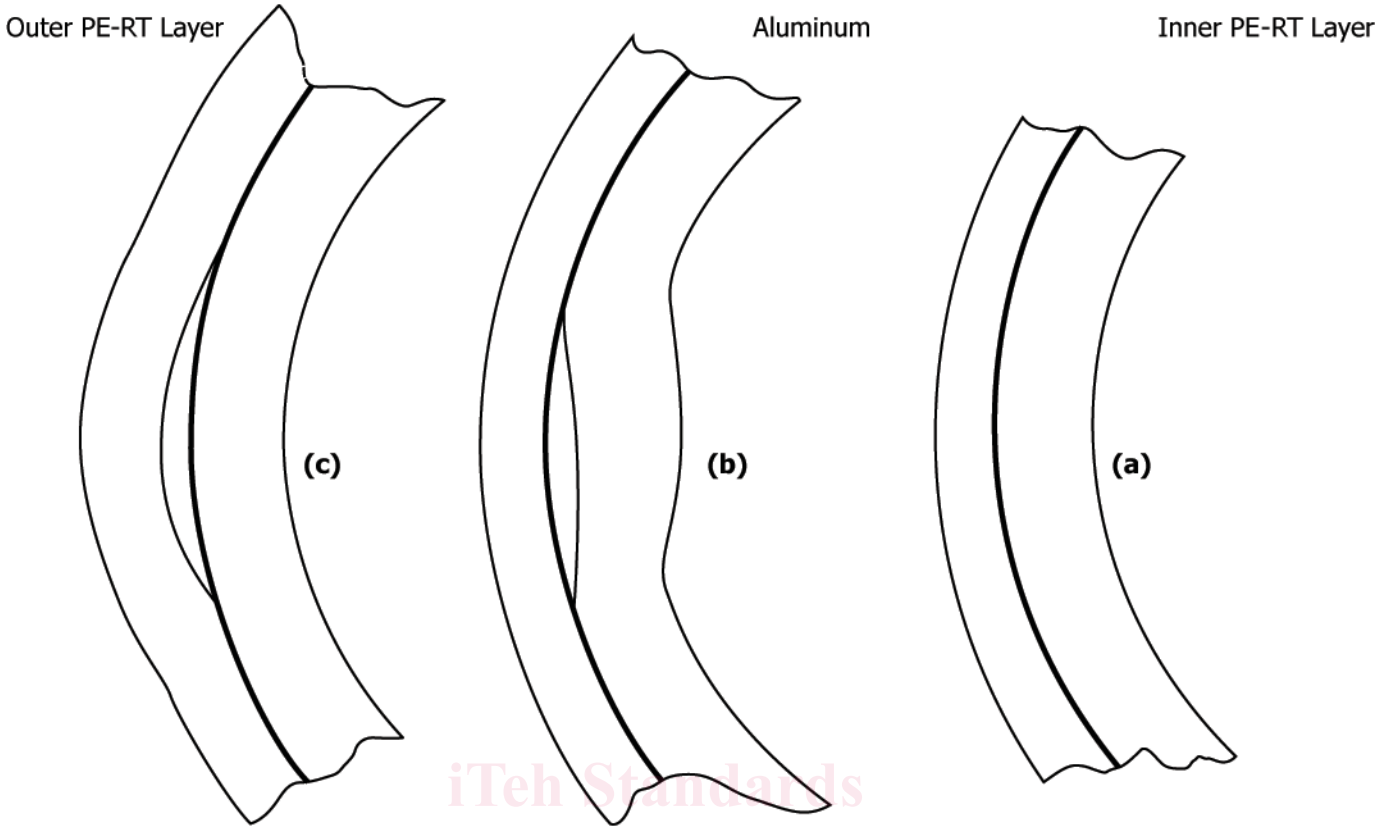

FIG. 1 Detection of Delamination

TABLE 3 Minimum Pipe Ring Strengths and 23 °C (73 °F) Burst Pressure of PE-RT/AL/PE-RT Composite Pipe

Nominal Pipe Size	Minimum Pipe Ring Strength N (lb)	Minimum 23 °C (73.4 °F) Burst Pressure, kPa (psi)
¼	2100 (470)	11032 (1600)
⅜	2200 (495)	11032 (1600)
½	2400 (540)	11032 (1600)
⅝	2400 (540)	11032 (1600)
¾	2400 (540)	11032 (1600)
⅞	2650 (595)	11032 (1600)
1⅛	3200 (720)	11032 (1600)

TABLE 4 Minimum Sustained Pressure for PE-RT/AL/PE-RT Composite Pipe

Nominal Pipe Size	Minimum Sustained Pressure PE-RT/AL/PERT, kPa (psi) at 60 °C (140 °F)	Minimum Sustained Pressure PE-RT/AL/PERT, kPa (psi) at 82 °C (180 °F)
¼	8274 (1200)	6895 (1000)
⅜	8274 (1200)	6895 (1000)
½	8274 (1200)	6895 (1000)
⅝	8274 (1200)	6895 (1000)
¾	8274 (1200)	6895 (1000)
⅞	8274 (1200)	6895 (1000)
1⅛	8274 (1200)	6895 (1000)

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

9.1.2 *Inside Diameter*—Measure the inside diameter of the PE-RT/AL/PE-RT pipe with internal calipers, telescopic bore gauge, or with optical measurement equipment. Measure the inside diameter at both ends of the pipe to the nearest 0.01 mm (0.0004 in.). Cut the ends of the pipe square and remove burrs before making a measurement.

9.1.3 *Wall Thickness*—Make micrometer 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 *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:*

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° spiral in the pipe (Fig. 2). Choose a PE-RT/AL/PE-RT pipe at random and insert into the housing and rotate to form the spiral cut. The cut goes through

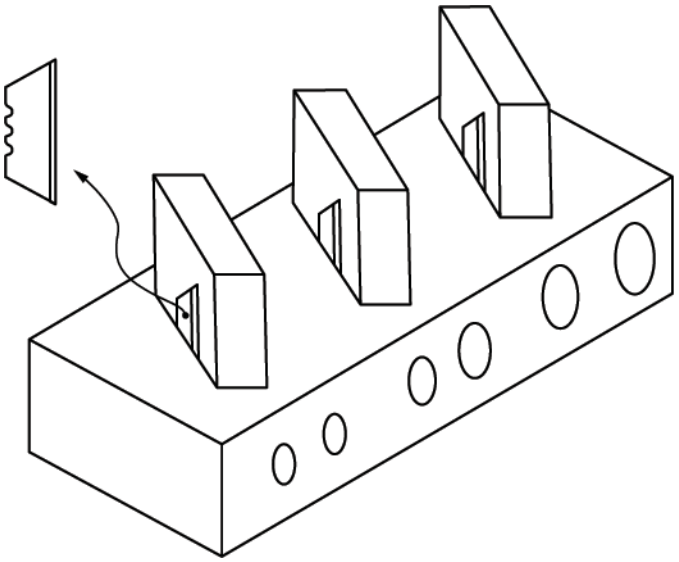

FIG. 2 Spiral Cutter for the Delamination Test

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-RT layer together with the aluminum) are separated mechanically from the inner PE-RT 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-RT 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 °C ± 2 °C (73 °F ± 3 °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-RT/AL/PE-RT pipe so that the two sides are parallel and at 90° ± 2° to the pipe axis. The length of each ring shall be 25 mm ± 1 mm (1 in. ± 0.04 in.). Cut a minimum of 15 samples consecutively along the axis *f* 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

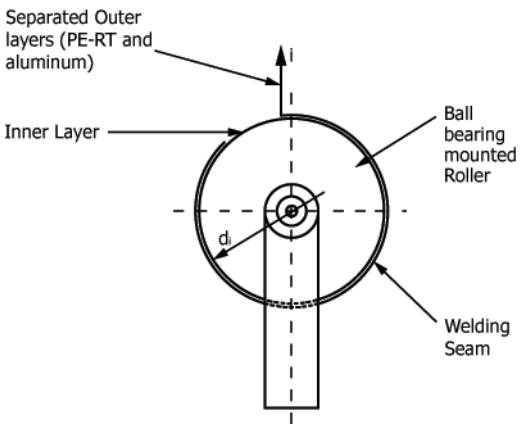

FIG. 3 Setup for Separation Test