Designation: C1847 – 21

Standard Specification for Direct Buried Pre-Insulated and Jacketed Polyurethane Bonded Low Temperature Hot Water Piping Systems[1]

This standard is issued under the fixed designation C1847; 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 direct buried underground pre-insulated, hot water piping systems with an upper temperature limit of 250 °F (121 °C) used to convey pressurized fluids for district heating. In the pre-insulated pipe industry and in this standard, this temperature range is called "low temperature hot water".

1.2 This specification shall not be used for low-pressure steam systems, steam trap discharge or pressurized condensate systems, since there is a high risk of exceeding the upper temperature limits. Pumped condensate return lines that are vented to atmosphere are considered to be low temperature hot water and are acceptable for this application.

1.3 This specification covers only piping systems insulated and jacketed with bonded polyurethane (PUR) rigid foam. A piping system consists of both straight sections of pre-insulated piping as well as pre-insulated fittings and field closures of the insulation system, and all materials required to ensure a water tight insulation system which will preclude water from entering the insulation from the surrounding soil. This specification does not encompass insulating or jacketing materials, or insulation methods, which do not produce factory, pre-fabricated, insulated and jacketed units for assembly at the field site.

1.4 The insulated piping systems covered by this specification do not possess an air gap between the carrier pipe and the insulation nor between the insulation and jacket. For straight pipe sections of the piping systems covered by this specification, these three components are bonded together.

1.5 The carrier piping that is part of the insulated piping system covered by this specification shall be designed, fabricated, and tested to the requirements of ANSI/ASME B31.1 (Power Piping).

1.6 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered to be the standard.

1.7 *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.*

1.8 *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]

A53/A53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

A105/A105M Specification for Carbon Steel Forgings for Piping Applications

A106/A106M Specification for Seamless Carbon Steel Pipe for High-Temperature Service

A234/A234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service

A312/A312M Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes

A403/A403M Specification for Wrought Austenitic Stainless Steel Piping Fittings

B88 Specification for Seamless Copper Water Tube

C168 Terminology Relating to Thermal Insulation

C335 Test Method for Steady-State Heat Transfer Properties of Pipe Insulation

C518 Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

C1409 Guide for Measuring and Estimating Quantities of Insulated Piping and Components

[1] This specification is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.40 on Insulation 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.

TABLE 1

Property	Value
Density, minimum lb./ft^3 (kg/m^3)	2.5 (40)
Compressive resistance at 10% deformation or yield, whichever occurs first, parallel to rise, minimum lb./in^2 (kPa)	40 (276)
Initial apparent thermal conductivity by Test Method C518 at a mean temperature of 75 °F (24 °C), BTU-in/hr-ft^2-°F (W/m-K)	[A]
Maximum aged apparent thermal conductivity, by Test Method C335 or ISO 8497 at mean temperatures shown in Table 2.	Table 2
Closed cell content per Test Method D6226, minimum %	88
Maximum linear change % at 250 °F per Test Method D2126	6
Assembly bond shear strength , minimum lb./in^2 (kPa) At 73 °F ± 4 °F (23 °C ± 2 °C) un-aged and thermally aged	17.4 (120)
Assembly bond shear strength, minimum lb./in^2 (kPa) Pipe at 284 °F ± 4 °F (140 °C ± 2 °C), un-aged and thermally aged	11.6 (80)
Visual Defects:	
Discolored streaks or areas	None significant
Soft or sticky spots	None significant
Cracks, gaps, disbondments	None significant
Voids	< 5% of cross section area
Largest dimension of any single void	< 25% insulation thickness

[A] The Manufacturer shall measure initial apparent thermal conductivity of the insulation on a monthly basis, shall maintain records of these values, and shall make these records available to the purchaser if requested. These initial apparent thermal conductivity values shall not be used to demonstrate compliance with the aged apparent thermal conductivity requirements in Table 2. For monthly quality control, the initial apparent thermal conductivity shall be determined in accordance with Test Method C518.

D883 Terminology Relating to Plastics
D1621 Test Method for Compressive Properties of Rigid Cellular Plastics
D1622 Test Method for Apparent Density of Rigid Cellular Plastics
D2126 Test Method for Response of Rigid Cellular Plastics to Thermal and Humid Aging
D2310 Classification for Machine-Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe (Withdrawn 2017)[3]
D2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
D6226 Test Method for Open Cell Content of Rigid Cellular Plastics
D7091 Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals

2.2 *ANSI/ASME Standards:*[4]
B16.9 Butt Welded Fittings
B16.11 Forged Fittings, Socket Welding and Threaded
B16.22 Wrought Copper Fittings
B31.1 Power Piping

2.3 *SSPC/NACE Standards:*[5]
SP-10 (NACE-2) Near-White Blast Cleaning
NACE-RP-0394 Application, Performance and Quality Control of Plant Applied Fusion Bonded Epoxy External Pipe Coating

3. Terminology

3.1 For descriptions of terms used in this specification, refer to Terminologies C168 and D883.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bonded, v*—a pre-insulated pipe insulation system where the insulation is sufficiently adhered to both the carrier pipe and jacket such that the system passes the testing for adhesive/bond strength required in Table 1.

3.2.2 *carrier pipe and fitting coating, n*—a tightly adhered layer of material that provides anti-corrosive protection to the external surface of the carrier pipe material.

3.2.3 *carrier pipe and fittings, n*—hollow tubular products capable of handling the pressures, temperatures, velocities, and damaging effects (corrosion, erosion, etc.) of the fluid being transported by the thermal distribution system.

3.2.4 *centering device, n*—a method or appliance used to assure the concentricity of the carrier pipe and fittings, thermal insulation, and insulation jacket.

3.2.5 *insulation jacket, n*—a casing or jacket of protective material applied around the thermal insulation under controlled

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from NACE International (NACE), 15835 Park Ten Pl., Houston, TX 77084, http://www.nace.org.

conditions at the time and location of application of the thermal system component thermal insulation.

3.2.6 *jacket outside diameter, n*—the sum of the carrier pipe outside diameter and twice the sum of the optional carrier pipe dry film coating thickness, insulation thickness, and jacket thickness.

3.2.7 *joining, v*—a method of connecting together two units of the thermal distribution system that maintains the strength and fluid tightness of the carrier pipe and fittings and the continuity and integrity of the insulation and jacket.

3.2.8 *leakage-free joint, n*—a group of methods for joining carrier piping sections and components using welding for steel and stainless steel, and brazing for copper that create rigid, pressure testable joints with zero leakage.

3.2.8.1 *Discussion*—All other joint types, including mechanical joints such as bell and spigot joints, sliding joints, and deformable gasket type joints are specifically not considered to be leakage-free and do not meet the requirement of this standard.

3.2.9 *pre-insulated, adj*—thermal insulation applied to the carrier pipe and fittings at the system supplier's manufacturing facilities.

3.2.9.1 *Discussion*—Thermal insulation applied at or near the system installation site by an installer or other organization not engaged in manufacturing pre-insulated system components does not conform to this definition.

3.2.10 *vapor (water) stop, n*—a device or method used at the terminations of a thermal distribution system (such as building and manhole entries) that prevent the ingress of water into the thermal insulation; alternatively a device or method that seals the ends of individual thermal distribution system units.

4. Ordering Information

4.1 Orders for thermal distribution systems purchased under this specification shall include the following information:

4.1.1 Thermal system service pressure, temperature and transported fluids.

4.1.2 Insulation thickness or heat transfer losses (or gains) per unit length of carrier pipe required, and the system environmental conditions that apply such as burial depth, soil conditions, and soil temperatures, etc.

4.1.3 Statutory or code requirements applicable to the carrier piping system design, fabrication, testing, inspection, and installation (see Annex A1).

4.1.4 Carrier pipe and fitting material specification and grade, size, pressure rating or wall thickness, configuration and end preparations (see Annex A1).

4.1.5 Optional carrier pipe and fitting coatings (see 5.2).

4.1.6 Thermal insulation material (see 5.3).

4.1.7 Thermal insulation jacket material (see 5.4).

4.1.8 Physical sizes and dimensions (see Section 7).

4.1.9 Field closure joint preferences (see Section 8).

4.1.10 Certification, inspection and testing requirements in addition to those specified (see Section 15).

4.1.11 Unit marking in addition to those specified (see Sections 16 and 17).

4.1.12 Shipping method if other than specified (see Section 18).

4.2 Order quantities for thermal distribution systems purchased under this specification shall be specified by providing all necessary point to point layout dimensional information, including slopes, termination points, direction changes, expansion loops, and all unique components and features. Thermal distribution systems purchased by this method are then provided as a fully engineered and pre-fabricated system comprised of units and joining materials that minimize installation time and the number of field joints required to complete the system.

4.3 Order quantities for thermal distribution systems purchased under this specification are in some cases specified by unit count. System orders under this method must be agreed between purchaser and supplier as to definitions and dimensions of system units, components, and materials. Guide C1409 is a useful guide for reaching agreement on layout measurement methods, unit and component definitions, and terminology. Thermal distribution systems purchased by this method require cutting standard unit lengths to size at least once in each run length and in most situations will result in a higher number of field joints, lower quality of the installation, and longer installation times.

5. Materials and Manufacture

5.1 *Carrier Pipe and Pipe Fitting Materials*—Carrier pipe and carrier pipe fitting material shall be selected from those materials listed in Annex A1 and shall meet the statutory and code requirements for design and service appropriate for the fluid temperature, pressure, longevity, chemical compatibility, and resistance to the damaging effects of corrosion.

5.2 *Optional Coating of Carbon Steel Carrier Pipe and Fittings*—When carbon steel carrier pipe and fitting materials have been specified, they are in some cases coated, as an option, to enhance corrosion resistance and service life. When this option has been ordered by the purchaser, the steel pipe and fitting outside surfaces shall be prepared by abrasive blasting to near white condition in accordance with SSPC-SP10 and primed or coated without delay to prevent the formation of rust bloom. The coating materials listed below are effective when applied by suitable spray techniques to the minimum thicknesses indicated. The dry film coating thickness shall be determined in accordance with Practice D7091.

5.2.1 *Epoxy Coating,* shall typically be a two part system consisting of a base material and curing agent (hardener). Factory applied fusion bonded epoxy to the requirements of NACE-RP-0394 is also acceptable. Dry film coating thickness shall be a minimum of 0.008 in. (200 µm).

5.2.2 *Zinc Rich Coating,* shall be a high solids, inorganic material consisting of a liquid vehicle and dry powdered zinc flake. Dry film coating thickness shall be a minimum of 0.003 in. (76 µm).

5.2.3 *Polymer Coating,* shall be an elastomeric polymer (plastic) usually consisting of polyurethane, polyurea, or a blend of both. Dry film coating thickness shall be a minimum of 0.020 in. (500 µm).

5.2.4 The coating selected and applied shall have been shown to be capable of withstanding the service temperature over the system life which is to be taken as 20 years unless otherwise specified. The coating selected shall be applied in compliance with the coating manufacturer's directions.

5.3 *Thermal Insulation Materials*—The thermal insulation shall be of closed cell, rigid, polyurethane (PUR) foam applied by spray or by injection. The PUR shall be free of color streaks, voids, cracks or gaps, soft spots, or other visual defects. The PUR insulation shall be bonded to the carrier pipe or optional coating to which it has been applied, and to the outer jacket. Open cell or un-bonded insulations do not meet the requirements of this specification.

5.4 *Thermal Insulation Jacket Materials*—The thermal insulation jacket shall be either high density polyethylene (HDPE) in accordance with 5.4.1 or filament wound, fiberglass reinforced polymer (FRP) in accordance with 5.4.2.

5.4.1 HDPE insulation jacket material shall meet the requirements of Specification D3350, with a minimum cell classification per Table 1 of Specification D3350 of PE 345444C. The HDPE jacket shall be applied by continuous extrusion or by fitting a tube of HDPE over the carrier pipe with centering devices prior to injecting the annular space with foam insulation. Both jacketing methods must provide permanent concentricity, within 15% of the insulation thickness, of carrier pipe, insulation and HDPE jacket and be fully bonded to the insulation without gaps or voids.

5.4.2 FRP insulation-jacket material shall be applied directly to the thermal insulation by machine filament winding, by chopped filament spray-up techniques, or by fitting a tube of FRP pipe over the carrier pipe with centering devices prior to injecting the annular space with foam insulation.

5.4.3 Both jacketing methods must provide permanent concentricity, within 15% of the insulation thickness, of carrier pipe, insulation and FRP jacket and be fully bonded to the insulation without gaps or voids. FRP pipe, when used, shall be in accordance with Specification D2996 and Classification D2310. All fittings shall be either a hand lay-up or chopped filament spray-up and have the same thickness and standards as the FRP jacket.

5.4.4 PVC jacket materials are not allowed. Tape type products constructed from any material are not permitted.

5.5 *Straight Pipe Units*—Straight pipe units manufactured to this specification shall meet the following requirements:

5.5.1 Both ends of the units shall be free of insulation and insulation jacket material for a distance of 6.0 ± 1.0 in. (150 ± 25 mm) to facilitate welding of the carrier pipe field joints without damage to the insulation system. When special welding equipment is to be used by the purchaser or by purchaser's system installers, the purchaser shall specify alternate end conditions and tolerance.

5.5.2 Units shall be free of bulges that exceed the nominal outside diameter by 5% or 1.0 in. (25 mm), whichever is less. Flat spots or areas of outside diameter reduction (necking) shall not deviate from the nominal outside diameter by more than 5% or 0.5 in. (13 mm), whichever is less.

5.6 *Pipe Fitting Units*—Pipe fitting units manufactured to this specification shall meet the following requirements:

5.6.1 Both ends of the units shall be free of insulation and insulation jacket material for a distance of 6.0 ± 1.0 in. (150 ± 25 mm) to facilitate welding of the carrier pipe field joints without damage to the insulation system. When special welding equipment is to be used by the purchaser or by purchaser's system installers, the purchaser shall specify alternate end conditions and tolerance.

5.6.2 Due to the complex shapes characteristic of pipe fittings such as "tees", reducers, and elbows, the insulation is optionally applied by building up sections of rigid foam or by injection conforming to the requirements of section 5.3. Regardless of method, all interstitial spaces and gaps created during build-up or injection shall be filled with foam. No voids or gaps are permitted.

5.6.3 The thermal insulation jackets of pipe fitting units shall be either high density polyethylene (HDPE) in accordance with 5.4.1 or fiberglass reinforced polymer (FRP) in accordance with 5.4.2, and shall match the jacket material of the straight units. HDPE insulation jackets are in some cases formed using built up sections, or by integral jackets produced by rotational molding or other methods that produce a single unit insulation jacket that conforms to 5.4.1. When the build-up method is used, the sections of HDPE jacket shall be joined by reinforced extrusion welds. Tapes, hot air welds, or shrink products are not permitted.

6. Performance Requirements

6.1 The units of the thermal distribution system shall be pre-insulated and supplied as a complete and compatible system to assure all components will be joined in accordance with the manufacturer's procedures.

6.2 The PUR shall meet the physical and thermal requirements of Table 1 and Table 2.

6.3 Insulation testing for process quality control shall be carried out on a monthly basis to ensure properties are in accordance with this specification. Specimens shall be taken from production units. Laboratory or specially prepared specimens do not comply with this specification except as noted in 6.3.3.

TABLE 2 Maximum Aged Apparent Thermal Conductivity

Required Mean Temp °F (°C)	Maximum Value BTU-in/hr-ft^2-°F (W/m-K)	Example Ambient Temp. °F (°C)	Example Pipe Temp °F (°C)
160 ± 5 (71 ± 3)	0.23 (0.032)	70 (21)	250 (121)
140 ± 5 (60 ± 3)	0.21 (0.030)	70 (21)	210 (99)
120 ± 5 (49 ± 3)	0.20 (0.029)	70 (21)	170 (77)

6.3.1 Density shall be determined in accordance with Test Method D1622.

6.3.2 Compressive strength shall be determined in accordance with Test Method D1621.

6.3.3 Initial apparent thermal conductivity shall be determined at a mean temperature of 75 °F (24 °C) in accordance with Test Method C518. For this test it is acceptable to make the required flat samples by spraying or injecting the PUR onto a flat surface. The resulting values are for manufacturing quality control purposes only per the footnote to Table 1.

6.3.4 Closed cell content shall be determined in accordance with Test Method D6226, and shall be the volume occupied by the closed cells and cell walls. It is not necessary to make the correction for surface cells opened by cutting that is described in Appendix XI of Test Method D6226.

6.3.5 Other physical or thermal properties are in some cases required, as agreed upon between purchaser and manufacturer.

6.4 Qualification testing shall be carried out initially and then every three (3) years thereafter and when a change in the manufacturing process, methods, or a material supplier has occurred. All testing shall be carried out by an independent laboratory accredited by a national or international accreditation agency. A report from the independent laboratory with its certification of the results must be provided complete and in unedited form. The report from the independent laboratory shall be made available to the Purchaser upon request. The report of the independent laboratory will contain all raw data as well as calculated quantities along with photographic evidence of test set up and test results. The following qualification testing is to be conducted:

6.4.1 Axial shear strength of the bonded pipe assembly shall be tested in accordance with the test method of Annex A2 in both the thermally aged and un-aged conditions.

6.4.2 Thermal conductivity shall be tested after aging. The aging process shall be accomplished by placing the entire pipe assembly in a heated chamber held at 195 °F ± 2 °F (91 °C ± 2 °C) for 150 days. Before the aging begins the exposed ends of the insulation shall be sealed to prevent diffusion of the cell gases. The pipe samples shall be 3 in. diameter pipe with minimum insulation thickness of 1.5 in. The pipe samples shall be tested in accordance with Test Method C335 or ISO 8497 using the guarded end method. The test shall be run to obtain apparent thermal conductivities at a minimum of three mean temperatures. Table 2 shows required values for mean temperature and apparent thermal conductivity, and examples of ambient and pipe temperatures for achieving these values.

6.4.3 Dimensional stability shall be conducted in accordance with Test Method D2126 at 250 °F (121 °C). Acceptance criteria are in Table 1.

7. Physical Sizes and Dimensions

7.1 For low temperature hot water service, the PUR insulation shall be applied to the minimum thicknesses in Table 3. The thickness tolerance on the minimum side shall not be more than 10%. Higher than normal energy costs or special services require an analysis of system heat transfer by the purchaser's or manufacturer's engineers to determine the additional insulation thickness required, if any. See Appendix X2 for reasons for thermal analysis and references to sources of methods. The additional insulation thickness for direct buried systems, if any, will depend on the thermal properties of the soil as determined by type classification, density and moisture content. Climatological factors at the installation site, system burial depth, operating temperature and other factors will in some cases also impact the appropriate insulation thickness. Heat transfer calculations for the buried system shall follow the procedure outlined in the District Heating and Cooling Chapter of the ASHRAE HVAC Systems and Equipment Handbook.

TABLE 3

Nominal Carrier Pipe Size inches (mm)	Minimum Insulation Thickness inches (mm)	Target Insulation Thickness inches (mm)
1 – 6 (25 – 168)	1.35 (34)	1.5 (38)
8 – 14 (219 – 355)	1.8 (46)	2.0 (50)
16 – 36 (406 – 915)	2.25 (57)	2.5 (63)

7.2 HDPE jacket thicknesses shall be as in Table 4.

7.3 FRP jacket thicknesses shall be as in Table 5.

8. Other Requirements

8.1 *Joining*—The most critical parts of thermal distribution system installations are the joints, whether they are factory made or field installed, where carrier pipe, insulation, and jacket continuity and moisture tightness must be maintained. All joining material and methods shall be supplied by the thermal distribution system manufacturer or if purchased separately from other sources, the field joint materials must conform to the requirements and installation instructions recommended by the thermal distribution system manufacturer.

8.1.1 Carrier pipe joints, for the carrier pipe and fitting materials of A1.2 and A1.3 shall be made in strict accordance to the requirements of the pressure pipe codes of ASME B31.1. No joints shall be allowed within pre-insulated straight sections of pipe.

8.1.2 Only welded or brazed joints of the carrier piping are allowed. Bell and spigot joints, sliding joints, flexible gasket joints, or other types of mechanical joints that have allowable leakage rates greater than zero are not permitted.

8.1.3 Copper joints shall be made by silver brazing with an alloy with a melt temperature of at least 1100 °F (593 °C). Tin-lead solders do not meet the requirements of this specification.

8.1.4 All carrier pipe joint strength and tightness testing, both factory and field performed, shall be in accordance with ASME B31.1 and shall be conducted and passed prior to the

TABLE 4

Jacket OD inches (mm)	Minimum HDPE Jacket Thickness inches (mm)	Target HDPE Jacket Thickness inches (mm)
OD ≤ 10 (254)	0.143 (3.6)	0.150 (3.8)
10 (254)< OD ≤ 18 (457)	0.166 (4.2)	0.175 (4.4)
18 (457)< OD ≤ 24 (610)	0.190 (4.8)	0.200 (5.1)
24(610)< OD ≤ 30 (762)	0.238 (6.0)	0.250 (6.4)
OD >30 (762)	0.261 (6.6)	0.275 (7.0)

TABLE 5

Jacket OD inches (mm)	Minimum FRP Jacket Thickness inches (mm)	Target FRP Jacket Thickness inches (mm)
OD ≤ 8 (203)	0.090 (2.3)	0.100 (2.5)
10 (254)< OD ≤ 14 (355)	0.135 (3.4)	0.150 (3.8)
16 (406)< OD ≤ 26 (660)	0.180 (4.6)	0.200 (5.0)
OD >26 (660)	0.225 (5.7)	0.250 (6.4)

application of coatings, insulation, or insulation jacket, which obscure the results of the test.

8.1.5 When a carbon steel carrier piping system corrosion preventive coating is used, the pipe joints shall also be coated to provide continuous coating protection. After the pipe joints have been properly fabricated and tested, the joint surfaces shall be coated using the system manufacturer's procedures for cleaning, preparation, and application of the coating. The factory and field joint coating thickness shall meet the same minimum dry film thickness required by the specifications or purchase order that apply to the carrier pipe and fittings, and shall be verified by measurements when specified. The dry film coating thickness shall be determined in accordance with Practice D7091.

8.1.6 After the optional coating has been properly applied to a factory or field joint and cured, or the uncoated joint properly cleaned, rigid polyurethane foam insulation shall be applied to the joint in accordance with the system manufacturer's instructions. The insulation shall be installed as *(1)* two reactive liquid parts, polyol and isocyanate, mixed by hand or mechanical means and poured into a joint mold surrounding the factory or field joint and cured, or *(2)* fitted with preformed polyurethane insulation cinched and banded in place, with gaps and interstitial spaces filled with reactive two part liquids as in *(1)*, or by *(3)* injecting the two part polyurethane constituents into a field joint mold using pressurized airless mixing equipment. Regardless of the method of application, the insulation shall be inspected for voids, gaps, cracks, and soft or incomplete or improperly cured insulation prior to the application of the insulation jacket.

8.2 *Factory and Field Joint Insulation Jackets*—The insulation at factory made and field made joints shall be sealed with cross-linked HDPE or polyolefin shrink products with heat activated mastic whose supplied thickness is not less than 0.060 in. (1.52 mm). When applied, the shrink products shall overlap on each end at least 4 in. (100 mm) and the combination of shrink pressure and mastic shall adhere them to the existing unit jackets. The shrink product selection shall be based on piping system environmental conditions such as burial depth, soil conditions, soil temperatures, etc., as agreed between purchaser and supplier. The minimum continuous operating temperature rating of the shrink product shall be 176 °F (80 °C). Prior to installation of the shrink product field closure the surfaces of the insulation jacket to which it will adhere must be prepared in accordance with the shrink sleeve manufacturer's instructions. An HDPE sleeve with a minimum thickness equal to the jacket thickness of the adjoining piping shall be installed over the shrink product during installation and left in place for protection during backfilling and eventual operation of the system. The length of the HDPE sleeve shall be such that it extends 2 in. (50 mm) beyond the shrink product on each side of the joint and it must be secured such that it will not move during the backfilling process.

8.2.1 Field joint products that are pressure tested for air leakage are in some cases selected, as agreed between purchaser and supplier. These products provide assurance that the field joint jackets are strong and leak-tight. When air testable products have been selected, the sequence of field joint completion must be modified from that described in 8.1.6. After the optional coating has been properly applied to a factory or field joint and cured, or the uncoated joint properly cleaned, the air testable product shall be fitted, installed, and tested in accordance with the manufacturer's instructions. Each joint shall be air tested at 5 psig (34.5 kPa) for sufficient time to soap test the joints for leaks. After satisfactory air test, the joint will be insulated with polyurethane foam, using techniques *(1)* or *(3)* of 8.1.6. Seal plugs shall be fitted into the test/fill/vent holes in the product in accordance with the manufacturer's instructions.

8.2.2 The FRP jacketed system joints are in some cases closed with a manual layup FRP jacket applied in accordance with the manufacturer's instructions. The FRP joint jacket shall have a thickness not less than the thickness of the system units and shall overlap the existing FRP unit jackets on each end by at least 4 in. (100 mm). All FRP joint jackets shall be feathered into the existing FRP jackets to prevent abrupt steps in the jacket surface.

8.3 *Pipe Caps And Unit End Protection*—All pipe and fitting ends shall be provided with snug fitting caps or snug fitted shrink material to protect joint end preparations (square cut or bevels) and prevent the collection of dirt and foreign material.

NOTE 1—Pipe and fitting units that have been boxed or containerized, or are of such size that they are readily wiped and cleaned by hand do not require pipe caps or shrink material protection as agreed between purchaser and supplier.

8.4 *End Seals*—As an option, to prevent intrusion of water and moisture into the insulation during storage, transportation, handling, and installation, each pre-insulated straight section of pipe and pre-insulated fittings shall have an end seal provided. In this case, the end seal shall be one of the following types:

8.4.1 Carrying the outer casing over tapered pipe insulation ends and extending it down and over the carrier pipe.

8.4.2 Using specially designed snug-fitting molded caps made of polyethylene or rubber of standard manufactured thickness.

8.4.3 Using snug-fitting high shrink recovery cross-linked HDPE or polyolefin shrink products.

8.4.4 Mastics or coating type seals do not meet the requirements of this specification.

9. Workmanship, Finish, and Appearance

9.1 The carrier pipe and fittings shall all be new unused material, free from pitting or other deterioration beyond the acceptance limits of the carrier pipe and fitting purchase specification standards or applicable code requirements as listed in Annex A1. Pipe and fitting end preparations shall be free of damage.

9.2 All insulation shall be free of voids as defined in Table 1.

10. Sampling

10.1 For purposes of sampling and testing, the lot of polyurethane insulation liquid materials (polyols and isocyanates), coating liquid and solid materials, HDPE constituent materials, or FRP materials shall be all the unique quantity of material purchased and delivered at one time to the pre-insulated piping manufacturer.

10.2 Samples for qualification testing of thermal insulation systems, when required by contract or purchaser specification, shall be produced using the production machinery and methods. Purchaser and supplier shall agree upon the number of units required for qualification testing. Qualification testing shall consist of material thermal and physical properties testing and inspection of representative system units.

10.3 Sampling for in-process testing of components and materials and final acceptance testing shall be for material thermal and physical properties, dimensional compliance with drawings and standards, and shall include at least one sample from each lot of material used to fabricate the thermal insulation system components.

10.4 Sampling for welding and factory joining operations, weld and joint non-destructive examination (NDE) shall be in accordance with applicable code requirements or purchaser's specifications or contract.

11. Specimen Preparation

11.1 Specimens shall be prepared in accordance with the standard test methods appropriate for the required tests and the test standards of Section 6.

12. Inspection

12.1 Acceptance inspection of the units and installation supplies shall be made at the supplier's manufacturing facilities and shall be as agreed upon by the manufacturer and purchaser.

12.2 *Load Inspection*—The thermal distribution system units and installation supplies shall be loaded and packaged as recommended by the manufacturer. The receiver of the pipe shall be aware of *(1)* the loading and packaging requirements for each mode of transportation used; *(2)* the continuance of proper handling in any multiple loading and unloading before arrival; and *(3)* any transportation incident (wreck). Before unloading, the receiver shall examine the load for transportation damage, particularly if the load has shifted, packaging is broken, or if there are signs of rough treatment. Damage is in some cases caused from over tightening tie-down straps or from the tie down straps not being located at the same point along the pipe barrel where the pipe supports are located. The pipe shall be examined for abrasion due to joint surfaces being in contact with each other or any hard object surface; and unpadded metal tie-down straps.

12.3 *Unit Inspection*—Each load of pipe and fittings shall be inspected and inventoried for conformance to product specifications and contract documents. System unit markings vary according to contract, the type of pipe, and the manufacturer. Observe the unloading, uncrating, storage and distribution of each unit, as applicable, and inspect each unit for damage, such as cuts, cracks, or gouges.

12.4 Damaged units might or might not be repairable depending on the type of pipe. Repairable units shall be repaired in accordance with the manufacturer's recommendations. Cracks or cuts up to 50% of the jacket thickness are in most situations repaired with a shrink sleeve meeting the requirements of 8.2. Cracks or cuts in HDPE jackets that are more than 50% of the jacket thickness shall be weld repaired by extrusion welding and then covered with a shrink sleeve meeting the requirements of 8.2. Cracks or cuts in FRP jackets that are more than 50% of the jacket thickness shall be repaired using FRP hand layups and then covered with a shrink sleeve meeting the requirements of 8.2. A maximum of two (2) repairs per pre-insulated piping component shall be allowed, and each repair shall be limited to a size of ½ by 6 in. or 3 $in.^2$. Units that cannot be repaired shall be clearly marked to prevent usage, in a manner acceptable to the supplier, and then removed from the job site.

12.5 All solvent cements, primers, coatings, cleaners, adhesives, and lubricant shipping packages and containers shall be inspected for leakage, bulging, discoloration, or other signs of shipping damage or deterioration. Inspect and verify all such packages and containers are marked legibly and match shipping documentation.

12.6 *Nested Pipe and Fittings*—The pipe interiors and exteriors shall be inspected for transportation damage. Follow manufacturer's recommendations for unloading. The units shall be removed with a padded forklift boom or with one or two fabric slings, depending on weight and length, and without disturbing other units.

13. Handling

13.1 Handling of the units to prevent damage shall be in accordance with manufacturer's recommendations. Typically handling procedures shall include the following precautions:

13.1.1 Avoid rough handling or dropping of the unit and resting the unit on hard objects that would create point loading. Unit sections shall not be rolled over rough or rocky ground. Prevent objects from being dropped or impacting the units.

13.1.2 Move individual units manually, with a padded forklift boom or with one or two fabric slings, depending on weight and length, and without disturbing other units. Do not use chains, wire ropes, backhoe buckets, or hooks.

13.1.3 Move packaging units only with forks or slings that go under the packaging units. Packaging is not normally designed to be lifted by a chain or cable attached only to the top of the unit.

14. Storage

14.1 Store units and installation materials in accordance with the manufacturer's recommendations.

14.1.1 Store units and materials under appropriate protective cover for adverse weather conditions or if the unprotected storage time might exceed the manufacturer's recommendation.