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An American National Standard

Standard Specification for Selection and Application of Field-Installed Cryogenic Pipe and Equipment Insulation Systems on Liquefied Natural Gas (LNG)-Fueled Ships[1]

This standard is issued under the fixed designation F3319; 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 provides requirements for the design of thermal insulation systems for cryogenic piping and equipment for liquefied natural gas (LNG)-fueled ship applications. Methods and materials for installation, including jacketing and vapor retarders, are also detailed.

1.2 The pipe and equipment operating temperature range addressed by this specification is from a temperature no warmer than –259°F (–162°C) to all temperatures colder.

1.3 These types of piping systems typically have a small diameter: 3 in. (80 mm) NPS and smaller. However, this specification is not limited to pipes that small.

1.4 This specification does not address the thermal insulation on either LNG fuel tanks or factory installed, pre-insulated pipe insulation assemblies.

1.5 The design of removable/reusable insulation systems is not addressed in this specification.

1.6 Structural design and physical strength of insulation systems are not addressed in this specification. However, the securement of jacketing systems is addressed.

1.7 For above ambient pipe and equipment not carrying LNG, see Practice F683 for insulation practices.

1.8 Insulation system weight is not a design criterion considered in this specification.

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

1.10 *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.*

1.11 *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]

C165 Test Method for Measuring Compressive Properties of Thermal Insulations
C168 Terminology Relating to Thermal Insulation
C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
C680 Practice for Estimate of the Heat Gain or Loss and the Surface Temperatures of Insulated Flat, Cylindrical, and Spherical Systems by Use of Computer Programs
C835 Test Method for Total Hemispherical Emittance of Surfaces up to 1400°C
C1136 Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation
C1729 Specification for Aluminum Jacketing for Insulation
C1767 Specification for Stainless Steel Jacketing for Insulation
C1809 Practice for Preparation of Specimens and Reporting of Results for Permeance Testing of Pressure Sensitive Adhesive Sealed Joints in Insulation Vapor Retarders
D696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between −30°C and 30°C with a Vitreous Silica Dilatometer
D1621 Test Method for Compressive Properties of Rigid Cellular Plastics
E84 Test Method for Surface Burning Characteristics of Building Materials
E96 Test Methods for Water Vapor Transmission of Materials

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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.

E136 Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C
E228 Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer
E831 Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis
F683 Practice for Selection and Application of Thermal Insulation for Piping and Machinery

2.2 *Other Standards:*
IGF Code International Code of Safety for Ships using Gases or Other Low-Flashpoint Fuels[3]
Fire Test Procedures Code IMO Resolution MSC 307 (88) Annex 1 Part 1 and Part 5 and Annex 2[3]
IMO SOLAS 1974 as amended through 2014, Chapter II-2 Regulations 5 and 6[3]
ISO 8497 Determination of steady-state thermal transmission properties of thermal insulation for circular pipes[4]
MSC 1-Circ 1558 Unified Interpretations of The IGF Code[5]
Title 46 CFR Part 38 Subpart 38.05-2 Design and Construction of Cargo Tanks[6]
Title 46 CFR Part 164 Subpart 164.109 Non-Combustible Materials (SOLAS)[6]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms relating to insulating materials used in this specification, refer to Terminology C168.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *rubber membrane vapor retarder, n*—relatively thick, flexible material acting as a vapor retarder, the primary component of which is a rubber or rubberized material such as rubberized asphalt, nitrile rubber, or butyl rubber, combined with one or more secondary components such as aluminum foil, plastic film, and mesh or nonwoven reinforcement.

4. Materials and Manufacture

4.1 Insulation and jacketing material specifications describe those materials that are intended for use in the indicated temperature ranges. The specifications and requirements outlined herein are not intended to prevent the use of materials provided that sufficient technical data are submitted to demonstrate that the proposed material is comparable in quality, effectiveness, durability, and safety to that prescribed by this specification.

4.2 All materials and material properties shall be verified for applicability for use at cryogenic temperatures.

NOTE 1—The metal materials used for construction of the pipe and equipment are usually austenitic stainless steel (see IGF Code).

NOTE 2—The heat transmission studies for a liquefied natural gas (LNG) cargo tank includes a maximum ambient still air temperature of 115°F (46°C) (see 46 CFR 38.05-2) and this design condition is being adopted in this specification for the LNG piping.

NOTE 3—Nitrogen gas at high flow rates, pressures, and temperatures will substantially reduce plant and pipelines downtime by providing efficient purging/blanketing, drying, pressure testing, leak testing, and product displacement solutions in a safe, inert manner. Heated nitrogen gas for purging or cleaning LNG piping and equipment is to be maintained in temperatures equal to or lower than the maximum temperature of 115°F (46°C) (see 46 CFR 38.05-2).

5. General Requirements

5.1 All safety requirements as applicable to ships such as those from the relevant flag administration, the International Convention for the Safety of Life at Sea (SOLAS), and the IGF Code are applicable to the insulation materials and systems described in this specification.

5.2 LNG fuel piping shall be considered a cold service system for both open deck and enclosed spaces. Insulation and the associated vapor retarders, adhesives, as well as insulation pipe fittings shall comply with one of the following flammability requirements:

5.2.1 Be non-combustible by virtue of complying with the criteria of one of the following three: (*1*) Test Method E136, (*2*) Part 1 of the MO Fire Test Procedures (FTP) Code, or (*3*) 46 CFR 164.109.

5.2.2 Have a low-flame spread characteristic as determined by IMO FTP Code, Annex 1, Part 5, by exhibiting a critical flux at extinguishment (CFE) not less than 20 kW/m^2, a heat of sustained burning (Qsb) not less than 1.5 MJ/m^2, a total heat released (Qt) not exceeding 0.7 MJ, a peak heat release rate (Qp) not exceeding 4.0 kW, and not generating burning droplets.

5.2.3 Exhibit a flame spread index not exceeding 25 as determined by Test Method E84.

5.3 All piping and fittings, such as elbows and tees, which carry LNG, shall be insulated and protected by an abuse-resistant protective jacketing or protective finish with an emittance determined by Test Method C835; for use in design calculations, see 5.7.1. Unless otherwise specified, all associated flanges and valves shall also be insulated and jacketed. For more detailed information, see Section 8.

5.4 All insulation systems shall be sealed against water vapor intrusion resulting from sustained high vapor pressure differences between the cold surfaces and the ambient air with a vapor retarder system (details addressed in this specification are found in Section 7). Vapor retarder systems shall have a permeance ≤0.01 perm (0.575 ng/(s-m^2-Pa).

NOTE 4—The designer is to consider the heat gain into the insulated pipes between the LNG fuel tank and the master gas valves (MGVs) when designing the safety system for the LNG fuel tank (see MSC 1-Circ 1558).

5.5 The mechanical insulation system designer shall determine and state whether pipe and equipment insulation are necessary for personnel protection, condensation control, or other design criteria. For design purposes, the warmest LNG temperature shall be –259°F (–162°C).

5.5.1 For personnel protection, the insulation thickness shall be designed to maintain the outer surface of the insulation system above 0°F (–17.7°C) at a chosen set of harsh ambient conditions. For other personnel protection design criteria,

[3] Available from International Maritime Organization (IMO), 4, Albert Embankment, London SE1 7SR, United Kingdom, http://www.imo.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 ics.org.ir.

[6] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.

select the climatic conditions for a geographic location based on the coldest dry bulb temperature expected and a low wind speed such as a maximum of 5 mph (8.05 km/h).

5.5.2 For surface condensation control, the insulation thicknesses shall be designed to maintain the surface temperatures at or above the design ambient dewpoint temperature for a chosen set of harsh ambient conditions (see 5.6 for details) so as to prevent surface condensation most of the time.

5.5.3 For any other design criterion, the insulation thickness shall be designed to achieve this criterion at a chosen set of harsh ambient conditions (see 5.6.3). The actual pipe or flat surface orientation and pipe size shall also be used in the insulation thickness calculations.

5.6 For surface condensation control, design to the following ambient conditions:

5.6.1 For above deck condensation control, ambient conditions are as follows: an air temperature of 80°F (26.7°C), an 85 % relative humidity (RH), and a 5 mph (8.05 km/h) wind speed.

5.6.2 For enclosed space condensation control, ambient conditions are as follows: an air temperature of 90°F (32°C), an 85 % RH, and a maximum wind speed associated with the required air changes per hour.

NOTE 5—At the design conditions in 5.6.1 and 5.6.2, surface condensation will still occur some of the time, but it will be minimized. Note that there are complex interrelationships among all of these specified design conditions and the insulation thickness necessary to prevent or at least minimize condensation. More information on this subject is found in the Young paper.[7]

5.6.3 If the default ambient conditions in 5.6.1 and 5.6.2 are not used as minimum design criteria for the prevention of surface condensation, then, as an alternative, harsh ambient conditions chosen for use in insulation system design shall take into account many factors including the climate at the intended ports at which the ship will dock, the climate along the intended path of transit, the possible higher humidity environment present in an indoor area of the ship through which the insulated pipe will pass, and the typical wind speed to which the insulated pipe will be exposed.

5.7 Insulation thicknesses shall be calculated using a computer program based on Practice C680.

5.7.1 Design calculations for cryogenic insulation normally use mean temperature-thermal conductivity values obtained by testing in a flat configuration using Test Method C177 or in a pipe configuration using ISO 8497. Design calculations will also require input of surface emittance determined by Test Method C835.

5.8 Piping and units of equipment with designated internal temperatures of 50°F (10°C) and below shall be insulated from their supports or the supports insulated from the structures to which they are attached. Insulation on supports shall be terminated with a vapor stop at all places where the insulation ends.

[7] Young, J., "Factors Influencing the Likelihood of Surface Condensation on Mechanical Systems Insulation," *Insulation Outlook*, July and August 2012.

5.9 Single-layered insulation construction is permitted on all surfaces operating when recommended by the insulation manufacturer; however, the manufacturer shall provide a means of minimizing condensation at the joints and seams. When double-layered insulation construction is recommended by the insulation manufacturer, it shall have staggered joints on all surfaces and the inner layer shall not have its joints sealed to allow for thermal expansion/contraction. When more than double-layered construction is specified, there shall be a secondary vapor retarder consisting of either a low-permeance insulation material with all joints sealed or a second vapor retarder membrane located between the second and third (that is, outer) insulation layers. See Section 7 for more details.

6. Insulation Materials

6.1 The manufacturer of the insulation material(s) shall have technical data showing appropriate performance for use at the cryogenic temperature ranges addressed by this specification. The insulation material(s) selected shall demonstrate acceptability for this cryogenic temperature use by being tested as follows.

6.1.1 This provided technical data shall include mean temperature-thermal conductivity data in accordance with Test Method C177 or ISO 8497 to a minimum mean temperature of –200°F (–129°C).

6.1.2 Insulation material(s) shall be tested and the test results reported for the following two properties: (*1*) for designing differential thermal expansion/contraction, coefficient of linear thermal expansion in the temperature range of 70° ± 10°F (21° ± 5.6°C) to –259° ± 10°F (–162° ± 5.6°C) using either of the Test Methods D696 or E831 and (*2*) for designing pipe supports, for insulation materials used within pipe supports, compressive resistance at a temperature of –259° ± 10°F (–162° ± 5.6°C) using the compressive resistance test method required by the relevant ASTM International material specification or either Test Methods C165 or D1621.

6.2 For the purposes of this specification, only the three insulation properties cited in 6.1 are required. Other properties of the thermal insulation material(s) exist but these are not required.

7. Vapor Retarders

7.1 Five general types of vapor retarders are possible in this specification so long as the tested system permeance is ≤ 0.01 perm (0.575 ng/(s-m^2-Pa): (*1*) a thick plastic material, (*2*) a thin film/sheet/laminate material, (*3*) a layer of cellular insulation material (for which permeance = permeability/thickness) in which all joints are sealed with vapor-retarding joint sealant system such that they too exhibit a suitably low permeance, (*4*) a rubber membrane vapor retarder, or (*5*) a vapor retarder mastic.

NOTE 6—Vapor retarder mastic permeance tests are sometimes conducted without reinforcement scrim present even though scrim is typically applied during field applications.

NOTE 7—While taped or sealed joints can be tested for water vapor permeance using Test Methods E96 in conjunction with Practice C1809, there exists today no publicly available data on the permeance performance of such joints.

7.2 Insulation systems using a single insulation layer (see 5.9) shall have a vapor retarder of one of the five types described in 7.1.

7.3 Insulation systems using only two insulation layers (see 5.4) shall have at least one vapor retarder. This primary vapor retarder shall be located on the outside of the outer layer of insulation and shall be either type (*1*), (*2*), (*4*), or (*5*) as described in 7.1. Another acceptable option is for the outer layer of insulation to act as the primary vapor retarder provided it meets the requirements of type (*3*) in 7.1.

NOTE 8—On double- or triple-layer cold insulation systems, the longitudinal and butt joints on the inner layer(s) of insulation are normally not sealed with joint sealant. This is done to allow this innermost layer the maximum possible movement in response to the potentially very large temperature changes that this layer will encounter from ambient to pipe operating temperature. This movement manifests as the joints in this innermost layer opening and closing to a significant degree. Vapor retarders are typically not applied to this innermost layer because the expected significant and repetitive movement at the joints would likely damage the vapor retarder system.

7.4 All systems using three or more insulation layers shall have at least two vapor retarders. The primary vapor retarder shall be located on the outside of the third or outermost layer of insulation and shall be either type (*1*), (*2*), (*4*), or (*5*) as described in 7.1. The secondary vapor retarder shall be located between the two outermost layers of insulation and shall be either type (*1*), (*2*), (*4*), or (*5*) as described in 7.1 or the outer layer of insulation will act as the secondary vapor retarder provided it meets the requirements of type (*3*) in 7.1.

7.5 The joints of all vapor retarders shall be sealed against water vapor intrusion using manufacturer-recommended methods such as heat sealing, compatible pressure-sensitive tape, double-sided self-sealing lap tape, and appropriate adhesive or sealant systems.

7.6 Vapor retarder sheet and film are those that conform to either Specification C1136, Types VII or IX. In all cases, their joints shall be sealed in accordance with 7.5.

8. Protective Jacketing/Protective Finishes

8.1 The insulation system shall be covered with either a protective jacket or protective finish suitable for withstanding the degree of mechanical abuse and corrosive effects anticipated while meeting any other performance requirements of the jacketing such as fire resistance or contact by green water for on-deck pipe. In addition, the protective jacketing or protective finish shall be sealed to minimize water intrusion.

NOTE 9—For design criteria related to surface temperature such as condensation control and personal protection, jacketing/finish selection can impact the required insulation thickness due to the different emittance values of varying jacket types. For these surface temperature related design criteria, jackets/finishes with a low surface emittance value increase thickness required, while jackets/finishes with a high emittance value decrease thickness required for any insulation material. This thickness reduction can be particularly important in shipboard pipe insulation applications where space constraints frequently limit the pipe insulation thickness that is possible.

8.2 *Aluminum Jacketing:*

8.2.1 Aluminum jacketing shall be coated on the exterior surface with a paint or film to provide increased corrosion resistance and to increase surface emittance. See Note 9.

8.2.2 Aluminum jacketing shall have a three-layer 3 mil (76 µm) thick poly-film moisture barrier factory heat laminated to the interior surface to help prevent corrosion of the interior surface of the metal jacketing.

8.2.3 Aluminum jacketing shall meet the following requirements:

8.2.3.1 Aluminum jacketing used on straight pipe shall comply with Specification C1729, Type II, IV, or V, Grade 1, Class A.

8.2.3.2 Aluminum jacketing used on elbows and fittings shall comply with Specification C1729, Type II, III, IV, or V, Grade 1 or 3, Class A.

8.3 *Stainless Steel Jacketing:*

8.3.1 Stainless steel jacketing used on straight pipe shall have a three-layer 3 mil (76 µm) thick poly-film moisture barrier factory heat laminated to the interior surface to help prevent corrosion of the interior surface of the metal jacketing.

8.3.2 Stainless steel jacketing shall meet the following requirements (see Note 10 for exterior surfaces):

8.3.2.1 Stainless steel jacketing used on straight pipe shall comply with Specification C1767, Type I, II, IV, or V, Grade 1 or 2, Class A.

8.3.2.2 Stainless steel jacketing used in elbows and fittings shall comply with Specification C1767, Type I, II, IV, or V, Grade 1 or 2, Class A or E.

NOTE 10—Stainless steel jacketing is not typically coated on the exterior surface. The user of this specification should be aware that the lower emittance of uncoated stainless steel jacketing (≤0.3) will increase the insulation thickness required for personnel protection or for condensation control design criteria. See Note 9.

8.4 *Metal Jacketing Securement:*

8.4.1 Metal jacketing shall be secured using Type 304 stainless steel banding and wing seals in accordance with metal jacketing manufacturer's instructions. Rivets, screws, or any other fastener capable of penetrating the underlying vapor retarder shall not be used to secure metal jacketing.

8.5 Because general performance criteria for protective jacketing and protective finishes are not specified, other types of jacketing and finishes not discussed in this section are in some cases acceptable for use over the thermal insulation and vapor retarder systems on the pipe and equipment. These other types of protective jacketing or protective finishes can include, but are not limited to, glass reinforced plastic (GRP), mastics reinforced with scrim, and rubber. If one of these materials is selected, instead of metal jacketing, the specifier shall write a detailed specification for that material and its performance requirements.

8.6 Because LNG pipes operate at below ambient temperatures, when design conditions are exceeded for any length of time, the exterior surface of the insulation system will become wet with water vapor condensation. It is required to design protective jacketing/protective finishing systems that will not be damaged or degraded by periodic wet conditions from condensate water.

9. Summarizing Insulation System Performance

9.1 See Table 1 summarizing required insulation system performance.