Designation: C667 – 17 (Reapproved 2022)

Standard Specification for Prefabricated Reflective Insulation Systems for Equipment and Pipe Operating at Temperatures above Ambient Air[1]

This standard is issued under the fixed designation C667; 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 the requirements for all metal prefabricated, reflective insulation systems for equipment and piping operating in air at temperatures above ambient. Typical applications are in nuclear power-generating plants and industrial plants.

1.2 Reflective insulation is thermal insulation that reduces radiant heat transfer across spaces by the use of surfaces of high reflectance and low emittance.

1.3 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.

1.4 *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.*

1.5 *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]

C168 Terminology Relating to Thermal Insulation

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

C411 Test Method for Hot-Surface Performance of High-Temperature Thermal Insulation

C835 Test Method for Total Hemispherical Emittance of Surfaces up to 1400°C

C854 Test Method for Resistance to External Loads on Metal Reflective Pipe Insulation (Withdrawn 1997)[3]

C1045 Practice for Calculating Thermal Transmission Properties Under Steady-State Conditions

C1058 Practice for Selecting Temperatures for Evaluating and Reporting Thermal Properties of Thermal Insulation

C1061 Test Method for Thermal Transmission Properties of Non-Homogeneous Insulation Panels Installed Vertically (Withdrawn 1995)[3]

C1371 Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers

3. Terminology

3.1 *Definitions:*

3.1.1 Terms relating to thermal insulation materials and testing are in accordance with Terminology C168.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *convection stops, n*—seals used to reduce convection losses.

3.2.2 *end supports, n*—structural members placed at the end of a unit of insulation and fastened to both the inner and outer case.

3.2.2.1 *Discussion*—The primary purpose of the end supports is to increase the structural integrity of the unit.

3.2.3 *inner case, n*—the innermost sheet of the unit of insulation (closest to the hot surface).

3.2.3.1 *Discussion*—The inner case may perform structural functions in addition to its thermal functions.

3.2.4 *insulation assembly, n*—an assembly of insulation units arranged and secured together in a prescribed order that comprises the complete insulation for a vessel, pump, pipeline, or other component for a single design objective.

3.2.5 *insulation system, n*—a collection of insulation assemblies, that when secured together in a prescribed order, comprises the complete insulation for a vessel, pump, pipeline, or other component for a single design objective.

[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.

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

3.2.6 *lap straps, n*—strips that overlap a longitudinal or circumferential joint in the insulation which aligns adjacent insulation units and may also serve to restrict air infiltration and convection losses and to shed external falling water.

3.2.6.1 *Discussion*—The lap straps may be integral with one piece of the outer case or separate strips secured to it.

3.2.7 *outer case, n*—the outermost sheet or the unit of insulation (farthest from the hot surface). It usually performs structural functions in addition to its thermal functions.

3.2.8 *penetrations, n*—openings in a unit of insulation from the cold surface through to the hot surface.

3.2.9 *reflective liners, n*—those reflective sheets or foil interposed between the inner and outer case to reflect radiant energy, to minimize emission of radiant energy, and to restrict internal convection.

3.2.10 *thickness, n*—(see Fig. 1).

3.2.11 *unit of insulation, n*—a single structurally independent assembly of inner case, outer case, reflective liners, and end supports (if required).

3.3 *Symbols:*

3.3.1 The symbols used in this specification have the following significance:

3.3.2 C_c, *n*—conductance based on the area of insulation at the cold surface.

4. Ordering Information

4.1 Ordering information shall include the following:

4.1.1 Service requirements including operating hot surface temperature, expected ambient temperatures, and ambient air velocities,

4.1.2 Expected service life and any special environmental exposures,

4.1.3 Permitted average thermal conductance based on hot pipe temperature and insulation cold surface temperature,

4.1.4 Personnel exposure surface temperature limitations,

4.1.5 Expected seismic, loading, and vibration exposures,

4.1.6 Purchaser's systems and equipment drawings,

4.1.7 Limits, if any, on size, maximum thickness, weight, or number of insulation units requiring removal for inspection,

4.1.8 Location of components or maintenance, or both, and systems requiring removal of units for inspections,

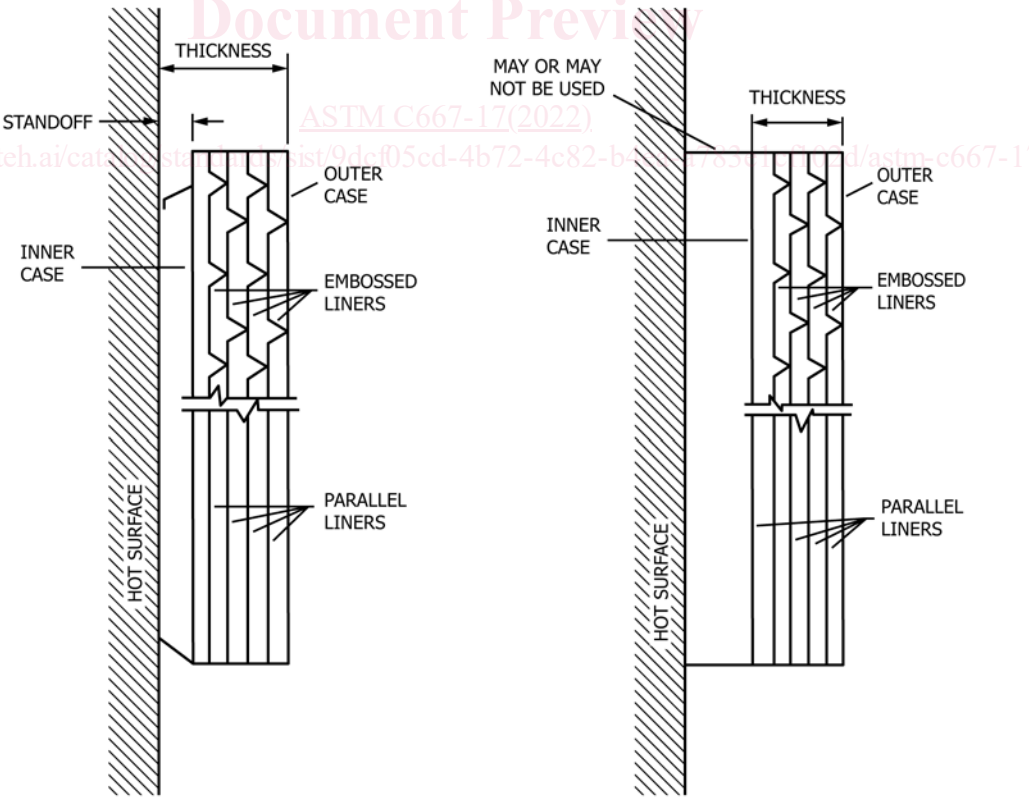
4.1.9 Any unusual operating or test conditions, and

4.1.10 Cleanliness level required.

5. Materials and Manufacture

5.1 Each insulation unit is a rigid, self-contained, prefabricated metal construction comprised of an inner casing and an outer casing, and if needed, one or more reflective liners supported and spaced so as to minimize internal convection and conduction. These parts are arranged to form a durable rigid assembly with separated air spaces between the inner and outer casing and the individual reflective liners.

5.2 The reflective insulation described herein is limited to systems of insulating units, designed by the manufacturer to fit



(a) Reflective Insulation Applied to Piping

(b) Reflective Insulation Applied to Equipment

FIG. 1 Illustration of Terms Relating to Prefabricated Reflective Insulation Systems

the equipment or piping to be insulated, and engineered for the purchaser's service requirements.

5.3 All parts of reflective insulation units shall be made of metals that meet the thermal, physical, and chemical requirements not only of the insulation as a unit, but also as an assembly of units forming the insulation system. The materials shall perform their functions for the service life specified and be compatible with the environment in which they will be used.

5.4 The stainless steel liners/foils shall be a minimum of 0.002 in. (0.05 mm) in thickness. Liners shall have an emittance of 0.25 or less when tested at 75 °F (24 °C) in accordance with Test Method C1371. There shall be a minimum of three foils per in. of insulation thickness. The options for the foils configuration are flat or patterned.

6. Temperature Limitations

6.1 Each insulation unit must effectively limit the flow of heat through the insulation by radiation, convection, and conduction. The reflective liners (also referred to as radiation shields or foils) are made of metals having low emittance and high reflectance. The emittance shall be tested in accordance with Test Method C835 or C1371. The number and spacing of the liners are determined by the required limitation of heat flow.

6.2 The temperature limits of various materials shall be based on the potential increase in radiant heat transfer across spaces due to a reduction in reflectance and a corresponding increase in emittance resulting from surface oxidation. Individual components of the insulation system operating at temperatures of 750 °F (400 °C) or higher shall not be made of aluminum or aluminum alloys. Components operating at 1200 °F (649 °C) or higher, shall be manufactured from Type 300 series austenitic stainless steel or material with the same properties.

6.3 A representative unit or assembly shall be tested in accordance with Test Method C411.

7. Thermal Performance

7.1 The purchase specification shall clearly indicate the permissible average rate of heat loss per unit area for each type of surface. The tests shall be in accordance with Test Method C335 for pipes, or Test Method C1061 for flat surfaces, or a test method agreed upon between the purchaser and manufacturer. Table 1 and Table 2 contain maximum tested values for thermal conductance based on specific installation conditions identified in notes A and B. Due to the fact that the thermal performance of metal reflective insulation depends on variables such as temperature, temperature difference, dimensions, emittance, and heat flow direction the manufacturer should be contacted for specific design recommendations regarding particular installation conditions. Butt joint heat losses shall be accounted for by including at least one butt joint within the metered area in the thermal performance test. Practices C1045 and C1058 shall be used for determining and reporting thermal transmission properties.

TABLE 1 Panels Thermal Conductance[A]

T_0 °F (°C)	T_2 °F (°C)	C (Btu/h ft^2)	C (W/m^{2}K)
298.8 (148.2)	91.6 (33.1)	0.073	0.412
513.0 (267.2)	112.6 (44.8)	0.097	0.548
720.2 (382.3)	142.1 (61.2)	0.135	0.769

[A]The thermal transmission properties of metal reflective insulation depends on temperature, temperature difference, dimensions, emittance, and heat flow direction. The thermal conductance data specified in Table 1 is based on a 4.625 in. thick specimen installed with a 1 in. space between the heated test surface and hot surface of the test specimen using an Test Method C1061 hot box apparatus with a 48 in. by 48 in. metering area that is oriented vertically (perpendicular to the ground). T_0 refers to the heat source surface temperature, T_2 is the insulation cold surface temperature, and C is the Thermal Conductance of the test sample. The testing was performed in accordance with 7.1.

TABLE 2 Piping Thermal Conductance[A]

Apparatus Orientation	T_0 °F (°C)	T_2 °F (°C)	C Btu/h ft^2 °F (W/m^{2}K)	C Btu/°F h ft^2 (W/m^{2}K)
Horizontal	296.8 (147.1)	100.5 (38.1)	0.186 (1.056)	0.112 (0.634)
Horizontal	447.8 (231.0)	135.9 (57.7)	0.232 (1.317)	0.139 (0.791)
Horizontal	702.3 (372.4)	174.1 (78.9)	0.298 (1.696)	0.179 (1.018)
Vertical	294.0 (145.6)	108.7 (42.6)	0.219 (1.242)	0.131 (0.746)
Vertical	494.9 (257.2)	151.3 (66.3)	0.282 (1.600)	0.169 (0.961)
Vertical	701.6 (372.0)	193.2 (89.6)	0.349 (1.982)	0.209 (1.190)

[A]The thermal transmission properties of metal reflective insulation depends on temperature, temperature difference, dimensions, emittance, and heat flow direction. The thermal conductance data specified in Table 2 is based on a 3 in. thick specimen with a 17.8 in. outer diameter installed on a 10 in. NPS Test Method C335 pipe test apparatus with metering length of 36 in. For purposes of calculating Cc, r0 = 5.40 in. and r2=8.99 in. The "Horizontal" apparatus orientation specified in the table refers to the fact that the central axis of the test apparatus was oriented parallel to the ground during testing. The "Vertical" apparatus orientation specified in the table refers to the fact that the central axis of the test apparatus was oriented perpendicular to the ground during testing. T_0 refers to the pipe temperature, T_2 is the cold insulation surface temperature, and C is the Thermal Conductance of the test sample. The testing was performed in accordance with 7.1.

7.2 Due to the limitation of present configurations of reflective insulation, those being flat, cone and cylindrical, there can be a significant difference between the hot equipment surface area and the outer case area. Therefore, the thermal performance for equipment shall be referenced to the area of the outer case, unless otherwise specified. For pipe, the pipe outside diameter shall be used – thermal conductance at the insulation cold surface is obtained by using 7.3.

7.3 Thermal performance of pipe insulation per unit of cold surface area shall be obtained by multiplying transference (T) or conductance (C) as determined by Test Method C335, where the outer surface area of the pipe is used to calculate C, by ratio of the radii of the test pipe outer radius (r_0) and the insulation outer surface radius (r_2). Example:

$$Cc = C \times r_o / r_2 \quad (1)$$

7.4 Heat loss test conditions shall include insulation orientation (horizontal or vertical) and the insulation joint design as specified in 8.3.

7.5 The specification shall not limit both heat loss through insulation and outer case temperature at the same time. If personnel exposure to high surface temperatures is considered to be a danger in limited areas, those areas shall be explicitly identified with the maximum allowable surface temperature and the ambient design conditions, and one or more of the following alternatives shall be used:

- External guarding,
- Additional insulation,

• High emittance outer case, or

• Other acceptable techniques agreed upon between the purchaser and the supplier.

7.6 Increased heat loss associated with modified insulation or reduced insulation thickness shall be identified.

8. Design and Construction

8.1 The insulation shall be of metal construction and shall form a system of prefabricated insulation units in integrated assemblies designed to fit the surfaces to be insulated with allowance for thermal expansion and contraction.

8.2 Insulation shall be designed to fit the specified surface, being insulated as necessary to limit heat losses due to convection and conduction. Insulation shall be manufactured so that edges or projections do not cause damage to the surface of the insulated pipe or equipment.

8.3 Insulation units shall have end (or edge) supports and convection stops at intervals as required to limit convective heat loss. Insulation units shall have banded and sealed ends, lapped or stepped ends, or a purchaser approved design that minimizes heat leakage at joints. Gaps required for thermal expansion or for internal unit construction are permitted when approved by the purchaser.

8.4 Insulation units and assemblies shall have the strength and rigidity to withstand specified seismic forces, and the operational loading and vibration requirements. Each unit shall have strength and rigidity to hold its internal parts in its spacial relationship without bunching or matting. Resistance to external loads shall be determined by the use of Test Method C854.

8.5 Insulation units and assemblies shall have provisions to retard entrance of liquids and to drain condensate, moisture, or other liquids from spill or other exposures specified in the ordering information.

8.6 Units shall have provisions to prevent internal pressure build-up.

8.7 Attachments, fasteners, and interlocking construction shall hold the insulation units firmly in place in the assemblies under all specified operating and test conditions. Locations of such items on interchangeable insulation units shall be matched.

8.8 Provisions shall be included for mating insulation to branch piping insulation at valves, pumps, and noncylindrical sections for penetrations through the insulation for instrumentation or other purposes.

9. Installation and Removal

9.1 Individual or groups of removable insulation units shall be provided for examination of component surfaces at locations shown on purchaser's drawings, or as otherwise specified or agreed upon between the purchaser and supplier. Insulation assembly design shall permit removal of such units with a minimum of disturbance to adjacent insulation units.

9.2 Insulation units shall be installed either individually or in groups so as to be able to perform replacement, maintenance, examination, and repairs of the insulated components with minimum disturbance of large portions of the insulation system. Limits on size of groups or number of units shall be as specified by the purchaser.

9.3 The insulation shall permit removal and reinstallation manually without the use of special tools unless otherwise specified by the purchaser.

9.4 The maximum weight of each individual insulation unit or combination units attached together during removal and reinstallation shall be as specified by the purchaser.

10. Cleaning

10.1 Materials shall be kept visibly free of oil, grease, and other dirt during all fabricating operations.

10.2 All materials' components shall be cleaned to an acceptable level as agreed upon between the purchaser and manufacturer.

10.3 Once cleaned, the surface shall be handled so as to limit, to the most practical extent possible, contamination from outside sources.

11. Installation and Inspection

11.1 Since prefabricated reflective insulations are custom-made to fit the vessel or piping to which they are to be installed, with casing lapping required for slip joints, water-shedding, and weather protection, they must be installed in proper sequence. The insulation manufacturer is expected to provide installation diagrams or procedures, or both, to show the proper sequence of installation.

11.2 Normally, insulation modifications shall be referred to the manufacturer. Field cutting or fitting shall be done in a workmanlike manner with cuts that are clean and neat and flashed to restrict air flow in or out of the insulation.

11.3 Units of insulation shall be installed in proper sequence with ends closely butted and with lap straps arranged to shed water.

11.4 Fitting, flange, and valve covers shall be installed to mate with straight pipe insulations.

11.5 Where insulation units are secured by bands and seals, the bands shall draw the assembly snug, but not so tight as to cause deformation of the assembly.

11.6 Insulation units, equipped with buckles or hinges and snap-locks, are placed in position and secured by fastening the snap-lock or buckle. For field variations of piping or fittings, adjustments shall be made for proper fit.

11.7 Where screws are used for securing piping and vessel insulation units, they shall be installed in properly drilled holes. Units shall be erected with screws securely tightened, or with locking devices to prevent loosening under vibration or movement. Screws shall not be used to secure telescoping assemblies where movement between adjacent units is needed to allow for expansion and contraction.

11.8 Insulation units shall be handled in such a manner so as to maintain the manufacturer's cleanliness level.