



# Standard Practice for Selection and Application of Thermal Insulation for Piping and Machinery<sup>1</sup>

This standard is issued under the fixed designation F683; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

## 1. Scope

1.1 This practice provides guidance in the selection of types and thicknesses of thermal insulation materials for piping, machinery, and equipment for nonnuclear shipboard applications. Methods and materials for installation, including lagging, are also detailed.

1.2 Supplemental requirements and exceptions to the requirements discussed herein for ships of the U.S. Navy are included in Supplementary Requirements S1.

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<sup>2</sup>

### 2.1 ASTM Standards:<sup>3</sup>

[A167 Specification for Stainless and Heat-Resisting](#)

[Chromium-Nickel Steel Plate, Sheet, and Strip \(Withdrawn 2014\)<sup>4</sup>](#)

[A653/A653M Specification for Steel Sheet, Zinc-Coated \(Galvanized\) or Zinc-Iron Alloy-Coated \(Galvannealed\) by the Hot-Dip Process](#)

[B209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate](#)

[B209M Specification for Aluminum and Aluminum-Alloy Sheet and Plate \(Metric\)](#)

[C168 Terminology Relating to Thermal Insulation](#)

[C195 Specification for Mineral Fiber Thermal Insulating Cement](#)

[C449/C449M Specification for Mineral Fiber Hydraulic-Setting Thermal Insulating and Finishing Cement](#)

[C533 Specification for Calcium Silicate Block and Pipe Thermal Insulation](#)

[C534 Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form](#)

[C547 Specification for Mineral Fiber Pipe Insulation](#)

[C552 Specification for Cellular Glass Thermal Insulation](#)

[C553 Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications](#)

[C610 Specification for Molded Expanded Perlite Block and Pipe Thermal Insulation](#)

[C612 Specification for Mineral Fiber Block and Board Thermal Insulation](#)

[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](#)

[C892 Specification for High-Temperature Fiber Blanket Thermal Insulation](#)

[C1482 Specification for Polyimide Flexible Cellular Thermal and Sound Absorbing Insulation](#)

[D962 Specification for Aluminum Powder and Paste Pigments for Paints](#)

[F1138 Specification for Spray Shields for Mechanical Joints](#)

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.02 on Insulation/Processes.

Current edition approved Aug. 1, 2014. Published December 2014. Originally approved in 1980. Last previous edition approved in 2010 as F683 – 10. DOI: 10.1520/F0683-14.

<sup>2</sup> The latest revision of all referenced documents shall apply.

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>4</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

## 2.2 Federal Specifications:<sup>5</sup>

**HH-P-31** Packing and Lagging Material, Fibrous Glass Metallic and Plain Cloth and Tape

**TT-P-28** Paint, Aluminum, Heat Resisting (1200°F)

## 2.3 Military Specifications:<sup>5</sup>

**MIL-PRF-24596** Coating Compounds, Nonflaming, Fire-Protective (Metric)

**DoD-E-24607** Enamel, Interior, Nonflaming (Dry), Chlorinated Alkyd Resin, Semigloss (Metric)

**DoD-I-24688** Type I, Insulation, Polyimide, Sheet and Tube

**MIL-A-3316** Adhesive, Fire-Resistant, Thermal Insulation

**MIL-A-24179** Adhesive, Flexible, Unicellular-Plastic, Thermal Insulation

**MIL-C-2861** Cement Insulation, High Temperature

**MIL-C-19565** Coating Compounds, Thermal Insulation Pipe Covering—Fire and Water-Resistant Vapor Barrier and Weather Resistant

**MIL-C-20079** Cloth, Glass, Tape, Textile Glass and Thread, Glass

**MIL-C-22395** Compound, End Sealing, Thermal Insulation Pipe Covering—Fire, Water, and Weather Resistant

**MIL-DTL-24441** Paint, Epoxy-Polyamide, Green Primer, Formula 150, Type III

**MIL-I-22023** Insulation Felt, Thermal and Sound Absorbing Felt, Fibrous Glass, Flexible

**MIL-I-2781** Insulation, Pipe, Thermal

**MIL-PRF-2818** Insulation Blanket, Thermal

**MIL-PRF-2819** Insulation, Block, Thermal

**MIL-I-16411** Insulation, Felt, Thermal, Glass Fiber

**MIL-PRF-22344** Insulation, Pipe, Thermal

**MIL-P-15280** Plastic Material, Unicellular (Sheets and Tubes)

**MIL-PRF-32161** Insulation, High Temperature Fire Protection, Thermal and Acoustic

**MIL-STD-769** Thermal Insulation Requirements for Machinery and Piping

**MIL-STD-2118** Trap, Steam, Angle, Thermostatic

## 2.4 Other Documents:

**Title 46** Code of Federal Regulations (CFR), Shipping (Parts 164.009 and 164.012)<sup>5</sup>

**EB 4013** Anti-Sweat and Refrigerant Insulation (Sheet and Tubes)<sup>6</sup>

**USCG Type Approval 164.109** IMO FTP Code Annex 1, Part 1<sup>7</sup>

**USCG Type Approval 164.112** IMO FTP Code Annex 1, Parts 2 and 5<sup>7</sup>

## 2.5 Drawings, NAVSHIP:

**803-5184182** Passive Fire Protection Insulation<sup>5</sup>

**804-5959214** Piping Insulation, Installation Details<sup>8</sup>

**804-5959212** Machinery Insulation, Installation Details<sup>5</sup>

## 2.6 NAVSEA:

**Naval Ships Technical Manual**, Chapter 635—Thermal, Fire, and Acoustic Insulation<sup>8</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms relating to insulating materials used in this practice, refer to Terminology **C168**.

## 4. Materials and Manufacture

4.1 *Insulation and Lagging Material Specifications*, as listed in **Tables 1-17**, 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 new test methods or materials, provided that sufficient technical data is submitted to demonstrate that the proposed test method or material is equivalent in quality, effectiveness, durability, and safety to that prescribed by this practice.

## 5. General Requirements

5.1 Piping, including valves, fittings, and flanges conveying vapors, gases, or liquids that attain temperatures outside the range from 55 to 125°F (13 to 52°C) during normal operation, shall be insulated except as otherwise stated herein.

5.2 The insulation thicknesses specified in this practice are designed to maintain the surface temperature at or below 125°F (52°C) for fluid temperatures up to 650°F (343°C) with an ambient temperature of 85°F (29°C). For fluid temperatures above 650°F, the surface will be maintained at a maximum of 133°F (56°C).

5.2.1 Insulation thicknesses have been calculated in accordance with the computer programs in Practice **C680**.

5.3 Piping and units of equipment with designated internal temperatures of 300°F (149°C) and over shall be insulated from their supports or the supports insulated from the structures to which they are attached where the heat transmitted is objectionable on the opposite side of the structure.

5.4 Insulated piping passing through accommodation, service, and control spaces must be covered with approved noncombustible materials, which meet 46 CFR, Sections 164.009 and 164.012, or USCG Type Approval 164.109 and 164.112 as issued by the USCG. Elastomeric foam rubber insulation shall not be used in these spaces.

5.5 Special consideration shall be given to the insulation of integral piping supplied with and mounted on equipment or machinery. In these cases, alternative materials and methods of installation shall be considered provided that they comply with the performance requirements of this practice.

5.6 Minimum insulation requirements have not been established for those surfaces or applications in which insulations had not been specified in past practices. In effect, the following surfaces are excluded from insulation requirements:

5.6.1 Surfaces where application of insulation will affect proper operation.

5.6.2 Equipment, components, and systems designed for the dispersion of heat.

<sup>5</sup> Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://dodssp.daps.dla.mil>.

<sup>6</sup> Available from General Dynamics, Electric Boat Corp., 75 Eastern Point Rd., Groton, CT 06340, <http://www.gdeb.com>.

<sup>7</sup> Available from International Maritime Organization, 4, Albert Embankment, London, SE1 7SR, United Kingdom, <http://www.imo.org/Pages/home.aspx>.

<sup>8</sup> Available from Naval Logistics Library, St. Louis, MO or on-line at <http://nll.ahf.nmci.navy.mil>.

**TABLE 1 Insulation and Lagging Materials for Pipe, Tubing, and Fittings Used for Interior Piping Systems<sup>A,B</sup>**

Temperature Range °F (°C)	Insulation	Specification	Insulation Covering <sup>C</sup>	Specification
-20 to +40 (-29 to +4)	cellular glass	C552, Type II	woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9 commercial
	polyimide foam <sup>D</sup>	C1482, Type I, with vapor retarder	sheet steel galvanized woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9
	elastomeric foam rubber <sup>A</sup>	MIL-P-15280, Form T EB 4013 C534, Type I	woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9
41 to 125 (5 to 51)	cellular glass	C552, Type II	woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9 commercial
	polyimide foam	C1482, Type I, with vapor retarder	sheet steel galvanized woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9
	elastomeric foam rubber <sup>A</sup>	MIL-P-15280, Form T EB 4013 C534, Type I	woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9
	mineral fiber <sup>D</sup>	C547, Type II	woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9 commercial
			sheet steel galvanized woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9 commercial
126 to 450 (52 to 232)	cellular glass	C552, Type II	woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9
	polyimide foam <sup>E</sup> 400°F (204°C) max	C1482, Type I	woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9
	elastomeric foam rubber <sup>A</sup> 180°F (82°C) max	MIL-P-15280, Form T EB 4013 C534, Type I	woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9
			sheet steel galvanized woven glass fiber	commercial
			sheet steel galvanized woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9 commercial
			sheet steel galvanized woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9 commercial
451 to 1050 (233 to 566)	cellular glass, 800°F (427°C) max	C552, Type II	woven glass fiber	MIL-C-20079, Type I, Classes 3 through 9 commercial
	mineral fiber	C547, Type IV, Grade A	sheet steel galvanized sheet steel black	commercial
	calcium silicate	C533	sheet steel black	commercial
	expanded perlite	C610	sheet steel black	commercial
			sheet steel black	commercial

<sup>A</sup> See 5.4.

<sup>B</sup> Insulation and insulation covering materials are acceptable for the temperature ranges indicated; other materials are capable of being used provided the requirements of this practice are satisfied. Thermal insulating tape is capable of being used as allowed by Section 8 of this practice.

<sup>C</sup> Lagging shall be used over insulation only.

<sup>D</sup> See Supplementary Requirements S1.5.

<sup>E</sup> See Supplementary Requirements S1.15.

5.6.3 Thermostatic steam traps and 24 in. (620 mm) of piping upstream of traps, which shall not be insulated. When located in areas in which personnel protection is required, expanded metal shields or multilayer glass cloth shall be provided.

5.6.4 Mechanical joints exposed to sub-atmospheric pressures and those included in the fuel oil service piping from heaters to burners.

5.6.5 Fuel oil piping between headers and burners.

5.6.6 Piping above 125°F (52°C) in bilges, not within watertight enclosures.

5.6.7 Piping in locations in which sweating and resultant rust is not objectionable such as voids, bilges, and shaft alleys, plus plumbing fixtures and associated supply and drain piping immediately adjacent thereto.

5.6.8 Dead-end hot water piping 3/8 in. (10 mm) and smaller.

5.6.9 Pressure-gage piping.

5.6.10 Soot-blower valve units and soot-blower flanges.

5.6.11 Piping in voids and cofferdams except where omitting insulation is detrimental to system operation, such as catapult steam.

5.6.12 Safety valve bodies, springs, and lifting gear.

5.6.13 Piping over shower stalls and behind and under lavatories.

5.6.14 Valves or flanges in the collection holding tank (CHT) system.

5.7 Higher-temperature-type insulations are capable of being used where lower-temperature-type insulations are specified, provided that they are satisfactory in all other respects.

5.8 In “high traffic” locations in which the completed insulation and lagging is liable to abuse, such as shipping, unshipping, and maintenance areas, protective sheet metal lagging shall be installed. Where metal lagging is required, any of the materials listed in Table 13 are acceptable, except for

**TABLE 2 Insulation and Lagging Materials for Pipe, Tubing, and Fittings Used for Weather-Exposed Piping Systems<sup>A</sup>**

Temperature Range °F (°C)	Insulation	Specification	Lagging <sup>B</sup>	Specification
-20 to +40 (-29 to +15)	cellular glass	C552, Type II	woven glass fiber cloth with outdoor mastic or metal jacketing	MIL-C-20079, Type I Class 7 (fittings) Class 9 (piping)
	polyimide foam	C1482, Type I	woven glass fiber cloth with outdoor mastic or metal jacketing with vapor retarder	MIL-C-20079, Type I Class 7 (fittings) Class 9 (piping)
	elastomeric foam rubber	MIL-P-15280, Form T	woven glass fiber cloth with outdoor mastic or metal jacketing	A167, Type 304
	elastomeric foam rubber	MIL-P-15280, Form T	woven glass fiber cloth with outdoor mastic or metal jacketing	MIL-C-20079, Type I, Classes 3 through 9
41 to 100 (5 to 37)	cellular glass	C552, Type II	corrosion-resistant steel	A167, Type 304
	polyimide foam	C1482, Type I	woven glass fiber cloth with outdoor mastic or metal jacketing	MIL-C-20079, Type I Class 7 (fittings) Class 9 (piping)
	perlite	C610	corrosion-resistant steel	A167, Type 304
	calcium silicate	C533	corrosion-resistant steel	A167, Type 304
	mineral fiber <sup>C</sup>	C547, Class 2 or 3	corrosion-resistant steel	A167, Type 304
	elastomeric foam rubber	MIL-P-15280, Form T	corrosion resistant steel	A167, Type 304
	elastomeric foam rubber	MIL-P-15280, Form T	woven glass fiber cloth with outdoor mastic or metal jacketing	MIL-C-20079, Type I, Classes 3 through 9
101 to 450 (38 to 232)	cellular glass	C552, Type II	corrosion-resistant steel	A167, Type 304
	polyimide foam <sup>B</sup> 400°F (204°C) max	C1482, Type I	corrosion-resistant steel	A167, Type 304
	perlite	C610	corrosion-resistant steel	A167, Type 304
	calcium silicate	C533	corrosion-resistant steel	A167, Type 304
	mineral fiber <sup>C</sup>	C547	corrosion-resistant steel	A167, Type 304
	elastomeric foam rubber	Type IV, Grade A MIL-P-15280, Form T	corrosion resistant steel	A167, Type 304
	elastomeric foam rubber 180°F (82°C) Max	MIL-P-15280, Form T	woven glass fiber cloth	MIL-C-20079, Type I, Classes 3 through 9
	elastomeric foam rubber 180°F (82°C) Max	MIL-P-15280, Form T	corrosion-resistant steel	A167, Type 304
	elastomeric foam rubber 180°F (82°C) Max	MIL-P-15280, Form T	woven glass fiber cloth	MIL-C-20079, Type I, Classes 3 through 9

<sup>A</sup> Insulation and lagging materials listed are acceptable for the temperature ranges indicated; other materials are capable of being used provided the requirements of this practice are satisfied.

<sup>B</sup> See Supplementary Requirements S1.15.

<sup>C</sup> See Supplementary Requirements S1.5.

boiler uptake applications in which metal lagging shall be galvanized sheet steel, in accordance with Specification **A653/A653M**, with Coating Designation G-115, and not less than 1/32 in. (0.8 mm) thick.

5.9 Before installing insulation, surface preparation of the piping is to be accomplished in accordance with the ship's painting schedule.

5.10 Lacing hooks shall be welded to the structure or equipment (with permission of the vendor of the equipment) for securing insulation to the equipment.

5.11 For bends, fittings, and so forth, where molded sections of pipe insulation cannot be used, mitered sections of the pipe

insulation or pre-formed fittings and covers shall be used, provided that they are suitable for the temperature and that the requirements of this practice are satisfied (see 4.1 and 5.4). Fittings in sizes under 2-in. (51-mm) nominal pipe size (NPS) shall be insulated with insulating cement, in accordance with Specification **C449/C449M**.

5.12 Where insulation specifications listed in **Tables 1 and 3** provide for the use of nonmetal "jacketed"-type insulation, separate lagging material shall be omitted.

5.13 Single-layered insulation construction shall be permitted on all surfaces operating at temperatures below 600°F (316°C). Double-layered insulation construction shall be used

**TABLE 3 Insulation and Lagging Materials for Machinery and Equipment<sup>A,B</sup>**

Temperature Range °F (°C)	Insulation	Specification	Lagging	Specification	
–20 to +40 (–29 to +4)	elastomeric foam rubber <sup>A</sup>	MIL-P-15280, Form S	woven glass fiber cloth	MIL-C-20079, Type I, Classes 3 through 9	
	polyimide foam	C1482, Type I	woven glass fiber cloth with vapor retarder	MIL-C-20079 Type I, Classes 3 through 9	
	cellular glass	C552, Type II	sheet steel galvanized	commercial <sup>C</sup>	
41 to 125 (5 to 51)	elastomeric foam rubber <sup>A</sup>	MIL-P-15280, Form S	woven glass fiber cloth	MIL-C-20079, Type I, Classes 3 through 9	
	polyimide foam	C1482, Type I	woven glass fiber cloth with vapor retarder	MIL-C-20079, Type I, Classes 3 through 9	
	cellular glass	C552, Type I	woven glass fiber cloth, or sheet steel black commercial	MIL-C-20079, Type I, Classes 3 through 9 commercial <sup>C</sup>	
	mineral fiber blanket	C553	sheet steel black, commercial or woven glass fiber cloth with vapor retarder	MIL-C-20079, Type I, Classes 3 through 9 commercial <sup>C</sup>	
	126 to 1200 (52 to 649)	glass fiber felt	MIL-I-16411	woven glass fiber cloth glass wire, reinforced	MIL-C-20079, Type I, Classes 7 or 9 HH-P-31, Type I
		polyimide foam <sup>D</sup> 400°F (204°C) max	C1482, Type I	woven glass fiber cloth	MIL-C-20079, Type I, Classes 3 through 8
refractory fiber blanket		C892, Grade 6 or 8	sheet steel black commercial or woven glass fiber cloth glass wire, reinforced	MIL-C-20079, Type I, Classes 3 through 9 HH-P-31, Type I	
elastomeric foam rubber (180°F (82°C) max)		MIL-P-15280 sheet	woven glass fiber cloth	MIL-C-20079, Type I, Classes 3 through 9	
	high-temperature insulating cement <sup>E</sup>	C195			
	calcium silicate insulating block	C553			
	mineral fiber blanket (1000°F (538°C) max)	C553, C612	sheet steel black, or fibrous glass cloth glass wire, reinforced	MIL-C-20079, Type I, Classes 3 through 9 HH-P-31, Type I	
	perlite	C610	woven glass fiber cloth	MIL-C-20079, Type I, Classes 3 through 9	

<sup>A</sup> See 5.4.

<sup>B</sup> Insulation and lagging materials are acceptable for the temperature ranges indicated; other materials are capable of being used provided the requirements of this practice are satisfied.

<sup>C</sup> With or without rewettable adhesive.

<sup>D</sup> See Supplementary Requirements S1.15.

<sup>E</sup> When insulating cement is used, it shall be applied in successive layers, ½ to 1 in. (13 to 25 mm) in thickness, until the total thickness specified in Table 7 has been reached. Galvanized iron wire netting, 1-in. (13-mm) mesh, shall be installed between layers. A ½-in. (13-mm) thickness of finishing cement, in accordance with Specification C449/C449M, shall be applied over the last layer of insulating cement.

with all joints staggered on all surfaces operating at temperatures of 600°F and above, except single-layered construction will be permitted when the total insulation thickness is 3 in. (75 mm) or less or the pipe size is NPS 2 in. (50 mm) or below.

## 6. Selection Requirements, Piping

6.1 *Interior Piping, Temperature Range from –20 to +40°F (–29 to +4°C)*—Use for air conditioning and ship's stores refrigerant piping and other services within the temperature range.

6.1.1 For insulation and lagging materials, see Table 1.

6.1.2 For insulation thickness, see Table 4 or Table 5.

6.1.3 For installation details, see Fig. 1, Fig. 2, or Fig. 3 as applicable.

6.2 *Interior Piping, Temperature Range from 41 to 125°F (5 to 52°C)*—Use for cold freshwater, plumbing drains, firemain, main and auxiliary, saltwater circulating, and saltwater cooling, piping, and other services within the temperature range.

6.2.1 For insulation and lagging materials, see Table 1.

6.2.2 For insulation thickness, see Table 2, Table 3, or Table 4.

6.2.3 For installation details, see Fig. 1, Fig. 2, or Fig. 3 as applicable.



**TABLE 4 Thickness of Cellular Glass Insulation for Piping, –20 to 800°F (–29 to 427°C)<sup>A</sup>**

Nominal Pipe Size, in. (mm)	Maximum Temperature, °F (°C) × Thickness, in. (mm)								
	–20 to 40 <sup>B</sup> (–29 to 4)	41 to 125 <sup>C</sup> (5 to 52)	250 (121)	350 (177)	450 (232)	550 (288)	650 (343)	750 (399)	850 (454)
¼ (6) and above	2½ (63) 1½ <sup>D</sup> (38)	1 (25) ½ <sup>D</sup> (13)	...	...	...	...	...	...	...
1½ (38) and below	...	...	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	3 (76)
2 (51)	...	...	1 (25)	2 (51)	1½ (38)	2 (51)	3 (76)	3 (76)	3½ (89)
2½, 3 (63, 76)	...	...	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3½ (89)	4 (102)
4 (102)	...	...	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)
5, 6 (127, 152)	...	...	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4½ (114)
8 (203)	...	...	1½ (38)	1½ (38)	2 (51)	3 (76)	3½ (89)	4 (102)	5 (127)
10 (254)	...	...	1½ (38)	1½ (38)	2 (51)	3 (76)	4 (102)	4 (102)	5 (127)
12 (305)	...	...	1½ (38)	1½ (38)	2½ (63)	3 (76)	4 (102)	4½ (114)	5½ (140)
14 (356)	...	...	1½ (38)	1½ (38)	2½ (63)	3½ (89)	4 (102)	4½ (114)	5½ (140)
16 (406)	...	...	1½ (38)	1½ (38)	2½ (63)	3½ (89)	4½ (114)	4½ (114)	5½ (140)
18 (457)	...	...	1½ (38)	1½ (38)	2½ (63)	3½ (89)	4½ (114)	4½ (114)	5½ (140)

<sup>A</sup> Thickness of cellular glass, in accordance with Specification C552, Type II.

<sup>B</sup> For refrigerant piping.

<sup>C</sup> For antisweat applications.

<sup>D</sup> Thickness for applications in air-conditioned spaces only.

**TABLE 5 Thickness of Elastomeric Foam Rubber Insulation Piping, –20 to 180°F (–29 to 82°C)<sup>A</sup>**

Nominal Size, in. (mm)	Temperature Range, °F (°C)	Nominal Thickness, in. (mm)	
		Non-conditioned spaces	Air conditioned spaces only
¼ (6) and above	–20 to 40 (–29 to 4) <sup>B</sup>	1½ (38)	1 (25)
	41 to 125 (5 to 52) <sup>C</sup>	¾ (19)	½ (13)
	126 to 180 (53 to 82)	½ (13)	½ (13)

<sup>A</sup> Thickness of elastomeric foam rubber insulation, conforming with MIL-P-15280, Form T, EB 4013 or C534, Type I.

<sup>B</sup> For refrigerant piping.

<sup>C</sup> For antisweat applications.

**TABLE 6 Thickness of Polyimide Foam Insulation Piping, –20 to 400°F (–29 to 204°C)<sup>A</sup>**

Nominal Size, in. (mm)	Temperature Range, °F (°C)	Nominal Thickness, in. (mm)	
		Non-conditioned spaces	Air conditioned spaces only
¼ (6) and above	–20 to 40 (–29 to 4) <sup>B</sup>	1½ (38)	1 (25)
	41 to 125 (5 to 52) <sup>C</sup>	¾ (19)	½ (13)
	126 to 180 (53 to 82)	½ (13)	½ (13)
	181 to 250 (83 to 121)	¾ (19)	¾ (19)
	251 to 350 (122 to 177)	1 (25)	1 (25)
	351 to 400 (178 to 204)	1½ (38)	1½ (38)

<sup>A</sup> Thickness of polyimide foam insulation conforming with Specification C1482.

<sup>B</sup> For refrigerant piping.

<sup>C</sup> For antisweat applications.

**6.2.4 Special Conditions:**

6.2.4.1 Piping systems operating in this temperature range including water closet drain piping do not require insulation except where damage or discomfort will result from condensation.

6.2.4.2 Dry firemain need only be insulated above ceilings and in areas in which damage or discomfort from condensation is a problem.

6.2.4.3 If cold, fresh, or potable water tanks (not having a side integral with the shell) are installed in a heated area, the piping to the pumps and therefore to the services need not be insulated. If this water is being used for flushing water closets, the drain piping need not be insulated.

6.2.4.4 Freshwater fill piping inside the ship shall be insulated.

6.2.4.5 Drains from drinking water chillers shall be insulated.

**6.3 Interior Piping, Temperature Range from 126 to 450°F (52 to 232°C)**—Use for hot freshwater, hot-water heating, fuel oil service discharge from heaters to headers, condensate, and air ejector piping, boiler feed, high- and low-pressure steam drain piping, and other services within the temperature range.

6.3.1 For insulation and lagging materials, see Table 1.

6.3.2 For insulation thickness, see Table 4, Table 5, Table 7, Table 8, or Table 9.

6.3.3 For installation details, see Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, or Fig. 6, as applicable.

6.3.4 *Special Conditions*—On piping, tubing, and fittings sized less than NPS ¾ in., insulation need be applied only where required for personnel protection.

**6.4 Interior Piping, Temperature Range from 451 to 1200°F (233 to 649°C)**—Use for main steam, auxiliary steam, exhaust and bleed steam, gland seal steam and exhaust, high- and low-pressure steam drains, soot blower steam, boiler blow, safety and relief valve escape steam heating, diesel exhaust piping, and other services within the temperature range.

6.4.1 For insulation and lagging materials, see Table 1.

6.4.2 For insulation thickness, see Table 4, Table 7, Table 8, or Table 9, as applicable.

6.4.3 For installation details, see Fig. 1, Fig. 4, Fig. 5, or Fig. 6, as applicable.

6.4.4 *Special Conditions:*

6.4.4.1 The soot blower piping between the root valve and the soot blower heads shall have an insulation thickness of one half of that indicated for a continually operating system at the same temperature.

**TABLE 7 Thickness of Mineral Fiber Insulation for Hot Piping, 850°F (454°C) Maximum<sup>A,B</sup>**

Nominal Pipe Size, in. (mm)	Maximum Temperature, °F (°C) × Thickness, in. (mm)							
	150 (66)	250 (121)	350 (177)	450 (232)	550 (288)	650 (343)	750 (399)	850 (454)
1½ (38) and below	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2 (51)	2½ (63)	3 (76)
2 (51)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	3½ (89)
2½, 3 (63, 76)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)
4 (102)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	4 (102)
5, 6 (127, 152)	1 (25)	1 (25)	1 (25)	2 (51)	2½ (63)	3 (76)	3½ (89)	4 (102)
8 (203)	1 (25)	1 (25)	1 (25)	2 (51)	2½ (63)	3 (76)	3½ (89)	4½ (114)
10 (254)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4½ (114)
12 (305)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	4½ (114)	4½ (114)
14, 16, 18 (356, 406, 457)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	4½ (114)	5 (127)

<sup>A</sup> Commercially known as woven glass fiber.

<sup>B</sup> Thickness of mineral fiber insulation in accordance with Specification C547, Class 2.

**TABLE 8 Thickness of Mineral Fiber Insulation for Hot Piping, 1050°F (566°C) Maximum<sup>A,B</sup>**

Nominal Pipe Size, in. (mm)	Maximum Temperature, °F (°C) × Thickness, in. (mm)									
	150 (66)	250 (121)	350 (177)	450 (232)	550 (288)	650 (343)	750 (399)	850 (454)	950 (510)	1050 (566)
1½ (38) and below	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2 (51)	2 (51)	2½ (63)	3 (76)	3½ (89)
2 (51)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	3 (76)	3½ (89)	4 (102)
2½, 3 (63, 76)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)	4½ (114)
4 (102)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3½ (89)	4 (102)	4½ (114)
5, 6 (127, 152)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3 (76)	3½ (89)	4½ (114)	5½ (140)
8 (203)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3 (76)	4 (102)	4½ (114)	5½ (140)
10 (254)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3½ (89)	4 (102)	5 (127)	6 (152)
12 (305)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)	5 (127)	6 (152)
14 (356)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4½ (114)	5½ (140)	6½ (165)
16 (406)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4½ (114)	5½ (140)	6½ (165)
18 (457)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	4 (102)	4½ (114)	5½ (140)	6½ (165)

<sup>A</sup> Commercially known as mineral wool.

<sup>B</sup> Thickness of mineral fiber insulation, in accordance with Specification C547, Class 3.

**TABLE 9 Thickness of Calcium Silicate Insulation (Specification C533) for Hot Piping, 1050°F (566°C) Maximum<sup>A</sup>**

Nominal Pipe Size, in. (mm)	Maximum Temperature, °F (°C) × Thickness, in. (mm)									
	150 (66) <sup>B</sup>	250 (121)	350 (177)	450 (232)	550 (288)	650 (343)	750 (399)	850 (454)	950 (510)	1050 (566)
1½ (38) and below	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	2½ (63)	3 (76)	3½ (89)
2 (51)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	3 (76)	3½ (89)	4 (102)
2½, 3, 4 (63, 76, 102)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3 (76)	3½ (89)	4 (102)	5 (127)
5, 6 (127, 152)	1½ (38)	1½ (38)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)	4½ (114)	5½ (140)
8 (203)	1½ (38)	1½ (38)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)	5 (127)	5½ (140)
10 (254)	1½ (38)	1½ (38)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4½ (114)	5 (127)	6 (152)
12 (305)	1½ (38)	1½ (38)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4½ (114)	5½ (140)	6 (152)
14 (356)	1½ (38)	1½ (38)	1½ (38)	2½ (63)	3 (76)	4 (102)	4 (102)	4½ (114)	5½ (140)	6½ (165)
16, 18 (406, 457)	1½ (38)	1½ (38)	1½ (38)	2½ (63)	3 (76)	4 (102)	4 (102)	5 (127)	5½ (140)	6½ (165)

<sup>A</sup> Thickness of calcium silicate insulation, in accordance with Specification C533.

<sup>B</sup> For indoor use only.

6.4.4.2 Main steam piping insulation shall be arranged with removable pads to bare sections for audio gaging when required.

6.4.4.3 Turbo-generator exhaust to main and auxiliary condensers do not require insulation except in areas susceptible to personnel contact.

6.4.4.4 Safety and relief valve escape piping need not be insulated except in areas susceptible to contact by personnel.

6.4.4.5 Boiler blow piping need not be insulated except in areas susceptible to contact by personnel.

6.4.4.6 On piping, tubing, and fittings sizes less than NPS ¾ in. (10 mm), insulation need be applied only where required for personnel protection.

6.4.4.7 Steam smothering and steam to the sea chests need be insulated only in those areas susceptible to personnel contact.

6.5 *Weather-Exposed Piping, Temperature Range from –20 to +60°F (–29 to +15°C)*—Use for low-temperature piping exposed to the weather.

6.5.1 For insulation and lagging materials, see **Table 2**.

6.5.2 For insulation thickness, see **Table 4**.

6.5.3 For installation details, see **Fig. 3**, **Fig. 7**, or **Fig. 8**.

6.5.4 *Special Conditions:*

6.5.4.1 Piping exposed to the weather shall also be effectively insulated against freezing. The thickness of insulation

**TABLE 10 Thickness of Perlite Insulation (Specification C610) for Hot Piping, 1050°F (566°C) Maximum<sup>A</sup>**

Nominal Pipe Size, in. (mm)	Maximum Temperature, °F (°C) × Thickness, in. (mm)									
	150 (66)	250 (121)	350 (177)	450 (232)	550 (288)	650 (343)	750 (399)	850 (454)	950 (510)	1050 (566)
1½ (38) and below	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	2½ (63)	3 (76)	3½ (89)
2 (51)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	3 (76)	3½ (89)	4 (102)
2½, 3, 4 (63, 76, 102)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3 (76)	3½ (89)	4 (102)	5 (127)
5, 6 (127, 152)	1½ (38)	1½ (38)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)	4½ (114)	5½ (140)
8 (203)	1½ (38)	1½ (38)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)	5 (127)	5½ (140)
10 (255)	1½ (38)	1½ (38)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4½ (114)	5 (127)	6 (152)
12 (305)	1½ (38)	1½ (38)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4½ (114)	5½ (140)	6 (152)
14 (356)	1½ (38)	1½ (38)	1½ (38)	2½ (63)	3 (76)	4 (102)	4 (102)	4½ (114)	5½ (140)	6½ (163)
16, 18 (406, 457)	1½ (38)	1½ (38)	1½ (38)	2½ (63)	3 (76)	4 (102)	4 (102)	5 (127)	5½ (140)	6½ (165)

<sup>A</sup> Thickness of perlite insulation, in accordance with Specification C610.

**TABLE 11 Thickness of Antisweat Insulation for Machinery and Equipment**

Temperature Range, °F (°C)	Material Specification	Nominal Thickness, in. (mm) <sup>A</sup>	
		Unconditioned Spaces	Conditioned Spaces
-20 to +40 (-29 to +4)	elastomeric foam rubber, C534, Type II	2 (51)	1 (25) <sup>B</sup>
	polyimide foam, C1482, Type I with vapor retarder	2 (51)	1 (25) <sup>B</sup>
41 to 125 (5 to 51)	cellular glass, C552, Type I	3 (76)	1½ (38) <sup>B</sup>
	elastomeric foam rubber, C534, Type II	¾ (19)	½ (13) <sup>B</sup>
	polyimide foam, C1482, Type I with vapor retarder	1 (25)	¾ (19) <sup>B</sup>
	cellular glass, C552, Type I	1 (25)	½ (13) <sup>B</sup>
	mineral fiber blanket, C553, C612	1 (25)	¾ (19) <sup>B</sup>

<sup>A</sup> Nominal thickness exclusive of vapor retarder.

<sup>B</sup> Thickness for application in air-conditioned spaces only.

required to prevent freezing is determined by calculation based on the system fluid, system velocity, type of insulation to be used, and climatic conditions involved. This does not apply to systems that are secured and drained.

6.5.4.2 At pipe supports, remove only enough insulation to provide a snug fit. Fill voids between insulation and support with tightly packed woven glass fiber felt, conforming with MIL-I-16411 to within ¼ in. (6 mm) of the insulation surface. Fill the remainder with end-sealing compound, conforming with MIL-C-22395, overlapping both the support member and the adjacent insulation. Lag and coat with the same materials as the adjacent pipe.

6.5.4.3 Alternatively, the lagged insulation and ends are permitted to be clad with metal lagging in lieu of end sealing compound.

6.6 *Weather-Exposed Piping, Temperature Range from 41 to 450°F (5 to 232°C)*—Use for hot piping systems exposed to weather.

6.6.1 For insulation and lagging materials, see Table 2.

6.6.2 For insulation thickness, see Table 4, Table 7, Table 8, or Table 9.

6.6.3 For installation details, see Fig. 3, Fig. 7, or Fig. 8.

6.6.4 *Special Conditions:*

6.6.4.1 Piping exposed to the weather shall be effectively insulated against freezing. The thickness of insulation required to prevent freezing is determined by calculation based on the system fluid, system velocity, type of insulation to be used, and

climatic conditions involved. This does not apply to systems that are secured and drained.

6.6.4.2 At pipe supports, remove only enough insulation to provide a snug fit. Fill voids between the insulation and support with tightly packed woven glass fiber felt, conforming with MIL-I-16411 to within ¼ in. (6 mm) of the insulation surface. Fill the remainder with end-sealing compound, conforming with MIL-C-22395, overlapping both the support member and the adjacent insulation. Lag and coat with the same materials as the adjacent pipe.

6.6.4.3 Alternatively, the lagged insulation and ends are permitted to be clad with metal lagging in lieu of end sealing compound.

## 7. Selection Requirements, Machinery and Equipment

7.1 *Temperature Range from -20 to +40°F (-29 to +4°C)*—Use for refrigerant and other equipment within the temperature range.

7.1.1 For insulation and lagging materials, see Table 3.

7.1.2 For insulation thickness, see Table 11.

7.1.3 For installation details, see Fig. 9, Fig. 10, or Fig. 11, as applicable.

7.2 *Temperature Range from 41 to 125°F (5 to 52°C)*—Use for low-temperature machinery and equipment within the temperature range.

7.2.1 For insulation and lagging materials, see Table 3.

7.2.2 For insulation thickness, see Table 11.

7.2.3 For installation details, see Fig. 9, Fig. 10, Fig. 11, or Fig. 12, as applicable.

7.2.4 *Special Conditions*—Machinery or equipment operating in this temperature range does not require insulation except where damage or discomfort will result from condensation.

7.3 *Temperature Range from 126 to 1200°F (52 to 649°C)*—Use for medium- and high-temperature machinery and equipment within the temperature range.

7.3.1 For insulation and lagging materials, see Table 3.

7.3.2 For insulation thickness, see Table 12.

7.3.3 For installation details, see Fig. 10, Fig. 11, Fig. 12, Fig. 13, or Fig. 14, as applicable.

## 8. Insulation and Lagging Requirements for Removable/ Reusable Blankets for Valves, Fittings, Flanges, and Machinery or Equipment

8.1 *Removable Covers*—Flanged valves and fittings and pipeline flanges shall have removable/reusable blankets to permit servicing of takedown joints.



**TABLE 12 Thickness of Insulating Materials for Hot Surfaces of Machinery and Equipment, 126 to 1200°F (52 to 649°C)**

Material	Maximum Temperature, °F (°C) × Thickness, in. (mm) <sup>A</sup>									
	150 (66)	250 (121)	350 (177)	450 (232)	550 (288)	650 (343)	750 (399)	850 (454)	950 (510)	1050 (566)
Woven glass fiber, MIL-I-16411	1 (25)	1 (25)	1½ (38)	2½ (63)	3 (76)	4 (102)	4 (102)	5 (127)	5½ (140)	6½ (165)
Block calcium silicate, <b>C533</b>	1½ (38)	1½ (38)	2 (51)	2½ (63)	4 (102)	4 (102)	4 (102)	5 (127)	5 (127)	5½ (140)
Block perlite, <b>C610</b>	1½ (38)	1½ (38)	2 (51)	2½ (63)	4 (102)	4 (102)	4 (102)	5 (127)	5 (127)	5½ (140)
Refractory fiber, <b>C892</b> , Grade 6	1 (25)	1 (25)	2 (51)	2½ (63)	3½ (89)	4½ (114)	4½ (114)	5½ (140)	6 (152)	7½ (191)
Refractory fiber, <b>C892</b> Grade 8	1 (25)	1 (25)	1½ (38)	2½ (63)	3 (76)	4 (102)	4 (102)	5 (127)	6 (152)	7 (178)
Mineral fiber, <sup>B</sup> <b>C553</b>	1½ (38)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	3½ (89)	4 (102)	4½ (114)	5 (127)
Elastomeric foam, <sup>C</sup> <b>C534</b> , Type II	½ (13)	½ (13)								
Polyimide foam, <b>C1482</b> <sup>D</sup>	¾ (19)	1 (25)	1½ (38)	2 (51)						
Insulating cement, <sup>E</sup> <b>C195</b>	2 (51)	2 (51)	2½ (63)	3½ (89)	5 (127)	5 (127)	5 (127)	5½ (140)		

<sup>A</sup> Does not include finishing cement.  
<sup>B</sup> 1000°F (537°C) maximum temperature.  
<sup>C</sup> 180°F (82°C) maximum temperature.  
<sup>D</sup> Shall not be used alone above 850°F (454°C).  
<sup>E</sup> See Supplementary Requirements S1.15.

**TABLE 13 Metal Lagging Materials<sup>A</sup>**

Material	Specification	Nominal Thickness, in. (mm)
Hot-dipped galvanized steel	<b>D962</b> Coating designation G-115	0.014 (0.356)
Aluminum	<b>B209</b> , 6061	0.030 (0.762)
Corrosion-resistant steel	<b>A167</b> , Type 304	0.014 (0.356)

<sup>A</sup> For use on piping and machinery insulation in locations where insulation is subject to abuse, except for uptake applications in which metal lagging shall be galvanized steel, Specification **D962**, Coating Designation G-115, not less than ½ in. (12.7 mm) thick.

8.1.1 Removable/reusable blankets shall be manufactured using materials specified in 8.2 – 8.4 and to thicknesses specified in Tables 4-7. Stitching, lacing, and quilting (required to prevent sagging) shall be accomplished with materials specified in 8.5 and as shown in Figs. 15-17.

8.1.2 Removable/reusable blankets are also manufactured from segments of block insulation or from preformed sectional pipe covering and molded (pre-formed) components. When a removable cover is made of segments of block insulation or preformed (pre-formed) sectional pipe covering, it shall be of the same material and thickness as the adjoining pipe insulation.

8.1.3 Alternatively, high temperature Nomex hook and loop fastened, removable and reusable fiberglass insulation pads, are permitted to be used for pipe, valve and fitting covers for temperatures up to 450°F (232°C). Insulation pads shall be made up of an inner pad of high temperature glass fiber felt blanket conforming with MIL-I-16411, encased in fiberglass cloth conforming with MIL-C-20079, with an outer silicone coated fiberglass cloth covering. High temperature Nomex Velcro fastenings are attached to the pad to secure it in place. Pads are a minimum 1-inch thick for applications up to 450°F (232°C). Thicker pads are available if required. (**Warning**—These pads do not require painting. Improper painting results in severe peeling. Water based enamel provides better results than most paints and will not peel unless disturbed. When painting is required, apply two coats of water based enamel conforming with MIL-PRF-24596, Rev. A, to the silicone coated outer covering. Avoid coating the Nomex Velcro with paint as this will affect its functionality.)

8.2 *Filler Materials for Removable Blankets:*

8.2.1 Glass fiber felt blanket, conforming with MIL-I-16411.

8.2.2 Refractory fiber felt blanket, in accordance with Specification **C892**, Grade 8.

8.2.3 Refractory fiber felt blanket, also in accordance with Specification **C892**, Grade 6.

8.2.4 Mineral fiber blanket, in accordance with Specification **C612**, Class 4.

8.3 *Covering or Encapsulating Materials for Removable/Reusable Blankets:*

8.3.1 For surface temperatures 450°F (232°C) and below, the filler shall be encapsulated with woven glass cloth, conforming with MIL-C-20079, Type I, Class 9 (see Fig. 18, Detail A).

8.3.2 For surface temperatures above 450°F (232°C), the entire outside surface shall be encapsulated with TY304 stainless steel wire mesh, 0.011-in. (0.25 mm) diameter, No. 60 density, and crimped (see Fig. 18, Detail B). Alternatively, the entire outside surface shall be encapsulated with fiberglass cloth, inserted with stainless steel reinforcement, in accordance with HH-P-31, Type I, Class 1.

8.3.3 The cold or top side of the surface shall be covered with glass cloth, conforming with MIL-C-20079, Type I, Class 9. The bottom and side surface areas shall be covered as follows:

8.3.3.1 Woven glass fiber cloth, shall be inserted with stainless steel wire reinforcement, conforming with HH-P-31, Type I, Class 1 (see Fig. 18, Detail C); or

8.3.3.2 Woven glass fiber cloth, conforming with MIL-C-20079, Type I, Class 9, with TY304 stainless steel wire mesh, 0.008-in. (0.21-mm) diameter and No. 60 density, shall be crimped sewn onto the fibrous cloth (see Fig. 18, Detail D); or

8.3.3.3 TY304 stainless steel wire mesh, 0.011-in. (0.25-mm) diameter and No. 60 density, shall be crimped (see Fig. 18, Detail E).

8.4 *Alternative Covering Materials* (for surface temperatures 450°F (232°C) and below, and for cold or top-side covering for temperatures above 450°F), are provided for removable blankets to be used in areas exposed to weather or where liquid penetration presents a fire hazard. Alternative coverings are as follows:

**TABLE 14 Thickness of Fiberglass Felt for Removable/Reusable Insulation Blankets<sup>A</sup>**

Nominal Pipe Size, in. (mm)	Maximum Temperature, °F (°C) × Thickness, in. (mm)									
	150 (66)	250 (121)	350 (177)	450 (232)	550 (288)	650 (343)	750 (399)	850 (454)	950 (510)	1050 (566)
½ (13)	1 (25)	1 (25)	1½ (38)	1½ (38)	2 (51)	2 (51)	2½ (63)	2½ (63)	3 (76)	3½ (89)
1 (25)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2 (51)	2½ (63)	3 (76)	3 (76)	3½ (89)
1½ (38)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	3 (76)	3½ (89)	4 (102)
2 (51)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	3 (76)	3½ (89)	4 (102)
3 (76)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3½ (89)	4 (102)	4½ (114)
4 (102)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3 (76)	3½ (89)	4 (102)	5 (127)
6 (152)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3 (76)	4 (102)	4½ (114)	5½ (140)
8 (203)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3½ (89)	4 (102)	5 (127)	5½ (140)
10 (254)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)	5 (127)	6 (152)
12 (305)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4½ (114)	5 (127)	6 (152)
14 (356)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4½ (114)	5½ (140)	6 (152)
16 (406)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4½ (114)	5½ (140)	6½ (165)
18 (457)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	4 (102)	4½ (114)	5½ (140)	6½ (165)

<sup>A</sup> Thickness of fiberglass felt, in accordance with MIL-I-16411.

**TABLE 15 Thickness of Nominal 8-lb/ft<sup>3</sup> (128-kg/m<sup>3</sup>) Refractory Fiber Blanket for Removable/Reusable Insulation Blankets<sup>A</sup>**

Nominal Pipe Size, in. (mm)	Maximum Temperature, °F (°C) × Thickness, in. (mm)									
	150 (66)	250 (121)	350 (177)	450 (232)	550 (288)	650 (343)	750 (399)	850 (454)	950 (510)	1050 (566)
½ (13)	1 (25)	1 (25)	1 (25)	1½ (38)	1½ (38)	2 (51)	2 (51)	2½ (63)	3 (76)	3 (76)
1 (25)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2 (51)	2½ (63)	3 (76)	3 (76)	3½ (89)
1½ (38)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	3 (76)	3½ (89)	4 (102)
2 (51)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	3 (76)	3½ (89)	4 (102)
3 (76)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3 (76)	3½ (89)	4 (102)	4½ (114)
4 (102)	1 (25)	1 (25)	1½ (38)	2 (50)	2½ (63)	3 (76)	3 (76)	3½ (89)	4 (102)	4½ (114)
6 (152)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3 (76)	4 (102)	4½ (114)	5 (127)
8 (203)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)	4½ (114)	5½ (140)
10 (254)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4 (102)	5 (127)	5½ (140)
12 (305)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4½ (114)	5 (127)	6 (152)
14 (356)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4½ (114)	5 (127)	6 (152)
16 (406)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4½ (114)	5 (127)	6 (152)
18 (457)	1 (25)	1 (25)	1½ (38)	2½ (63)	3 (76)	3½ (89)	4 (102)	4½ (114)	5½ (140)	6 (152)

<sup>A</sup> Thickness of 8-lb/ft<sup>3</sup> (128-kg/m<sup>3</sup>) refractory fiber blanket in accordance with Specification C892, Grade 8.

**TABLE 16 Thickness of Nominal 6-lb/ft<sup>3</sup> (96-kg/m<sup>3</sup>) Refractory Fiber Blanket for Removable/Reusable Insulation Blankets<sup>A</sup>**

Nominal Pipe Size, in. (mm)	Maximum Temperature, °F (°C) × Thickness, in. (mm)									
	150 (66)	250 (121)	350 (177)	450 (232)	550 (288)	650 (343)	750 (399)	850 (454)	950 (510)	1050 (566)
½ (13)	1 (25)	1 (25)	1 (25)	1½ (38)	1½ (38)	2 (51)	2 (51)	2½ (63)	2½ (63)	3 (76)
1 (25)	1 (25)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	2½ (63)	3 (76)	3½ (89)
1½ (38)	1 (25)	1 (25)	1½ (38)	1½ (38)	2 (51)	2½ (63)	2½ (63)	2½ (63)	3 (76)	4 (102)
2 (51)	1 (25)	1 (25)	1½ (38)	1½ (38)	2 (51)	2½ (63)	2½ (63)	3 (76)	3½ (89)	4 (102)
3 (76)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3 (76)	3½ (89)	4 (102)	4½ (114)
4 (102)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)	3 (76)	3½ (89)	4½ (114)	5 (127)
6 (152)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)	4½ (114)	5½ (140)
8 (203)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)	5 (127)	5½ (140)
10 (254)	1 (25)	1 (25)	1½ (38)	2 (51)	3 (76)	3½ (89)	3½ (89)	4½ (114)	5 (127)	6 (152)
12 (305)	1 (25)	1 (25)	1½ (38)	2½ (63)	3 (76)	3½ (89)	4 (102)	4½ (114)	5½ (140)	6 (152)
14 (356)	1 (25)	1 (25)	2 (51)	2½ (63)	3 (76)	3½ (89)	4 (102)	4½ (114)	5½ (140)	6½ (165)
16 (406)	1 (25)	1 (25)	2 (51)	2½ (63)	3 (76)	3½ (89)	4 (102)	4½ (114)	5½ (140)	6½ (165)
18 (457)	1 (25)	1 (25)	2 (51)	2½ (63)	3½ (89)	3½ (89)	4 (102)	5 (127)	6 (152)	6½ (165)

<sup>A</sup> Thickness of 6-lb/ft<sup>3</sup> (96-kg/m<sup>3</sup>) refractory fiber blanket in accordance with Specification C892, Grade 6.

8.4.1 Silicone-impregnated woven glass fiber cloth,

8.4.2 Silicone-impregnated woven glass fiber cloth with aluminized facing on one side, and

8.4.3 Fiberglass cloth with aluminum or stainless steel facing laminated to one side.

8.5 *Hardware and Accessory Items for Removable/Reusable Blanket Construction*—Necessary items shall include blanket lacing devices, blanket quilting devices, stitching materials, and installation materials.

8.5.1 *Blanket Lacing Devices:*

8.5.1.1 TY304 stainless steel lacing rings with lacing washers (see Fig. 19).

8.5.1.2 TY304 stainless steel lacing hooks with lacing washers (see Fig. 20).

8.5.1.3 TY303 stainless steel lacing capstan assembly sets (see Fig. 21).

8.5.1.4 TY304 stainless steel mechanical hook sets (see Fig. 22).

**TABLE 17 Thickness of Fiberglass Blanket for Removable/ Reusable Insulation Blankets<sup>A</sup>**

Nominal Pipe Size, in. (mm)	Maximum Temperature, °F (°C) × Thickness, in. (mm)							
	150 (66)	250 (121)	350 (177)	450 (232)	550 (288)	650 (343)	750 (399)	850 (454)
½ (13)	½ (13)	½ (13)	1 (25)	1 (25)	1½ (38)	2 (51)	2½ (63)	3 (76)
1 (25)	½ (13)	½ (13)	1 (25)	1½ (38)	2 (51)	2 (51)	2½ (63)	3 (76)
1½ (38)	½ (13)	½ (13)	1 (25)	1½ (38)	2 (51)	2 (51)	3 (76)	3½ (89)
2 (51)	½ (13)	½ (13)	1 (25)	1½ (38)	2 (51)	2 (51)	3 (76)	4 (102)
3 (76)	½ (13)	½ (13)	1 (25)	1½ (38)	2 (51)	2 (51)	3 (76)	4 (102)
4 (102)	½ (13)	½ (13)	1 (25)	1½ (38)	2½ (63)	2½ (63)	3½ (89)	4½ (114)
6 (152)	½ (13)	½ (13)	1 (25)	2 (51)	2½ (63)	2½ (63)	3½ (89)	5 (127)
8 (203)	½ (13)	½ (13)	1 (25)	2 (51)	2½ (63)	2½ (63)	4 (102)	5 (127)
10 (254)	½ (13)	½ (13)	1½ (38)	2 (51)	2½ (63)	2½ (63)	4 (102)	5½ (140)
12 (305)	½ (13)	1 (25)	1½ (38)	2 (51)	2½ (63)	2½ (63)	4 (102)	5½ (140)
14 (356)	½ (13)	1 (25)	1½ (38)	2 (51)	3 (76)	4 (102)	4 (102)	5½ (140)
16 (406)	½ (13)	1 (25)	1½ (38)	2 (51)	3 (76)	4 (102)	4½ (114)	5½ (140)
18 (457)	½ (13)	1 (25)	1½ (38)	2 (51)	3 (76)	4 (102)	4½ (114)	6 (152)

<sup>A</sup> Thickness of fiberglass blanket, in accordance with Specification C612, Type II, C553, Type IV.

### 8.5.2 Blanket Quilting Devices:

8.5.2.1 TY304 stainless steel mechanical quilt sets (see Fig. 23).

8.5.2.2 TY304 stainless steel lacing washers with lacing wire (see Fig. 23).

### 8.5.3 Stitching Materials:

8.5.3.1 TY304 stainless steel hog rings.

8.5.3.2 TY304 stainless steel thread (0.011-in. (0.25-mm) diameter).

8.5.3.3 TY304 stainless steel staples.

8.5.3.4 Fiberglass thread (plain, polytetrafluoroethylene coated and wire inserted with monel or TY304 stainless steel, or both).

### 8.5.4 Installation Materials:

8.5.4.1 No. 18 gage copper lacing wire.

8.5.4.2 No. 18 gage soft or annealed TY304 stainless steel lacing wire.

8.5.4.3 No. 18 gage galvanized iron lacing wire.

8.5.4.4 TY304 stainless steel hog rings (particularly for installing thermal tape, refer also to Section 9).

### 8.6 Special Conditions:

8.6.1 Reusable covers for machinery and equipment shall be fabricated from materials specified in Tables 14-17, in accordance with methods shown in Fig. 18 and configured to suit the specific application.

8.6.2 Unfired pressure vessels with butt welded inserts for which periodic radiographic inspection of the joint is required shall have removable reusable covers installed over the insert. These covers shall extend 4 in. (100 mm) beyond the weld joint.

8.6.3 Removable/reusable blankets shall not be used on systems insulated with elastomeric-foamed plastic insulation.

8.6.4 Services subject to frequent maintenance, such as reducing and regulating valves, shall be provided with easily removed and replaced tailored pads.

8.6.5 Removable/reusable blankets shall not be used on cold systems (below ambient) or on systems where a vapor barrier is required.

8.6.6 When stitching two or more covering or encapsulating materials together, stainless steel staples, hog rings, 0.011-in. (0.25-mm) diameter stitching wire, or fiberglass thread (plain or wire inserted) shall be used.

8.6.7 All construction details apply to removable/reusable blankets for flanges, valves, machinery and equipment, and other miscellaneous areas as determined by the specifier.

8.6.8 When installing removable/reusable blankets on valves, flanges, and various pieces of equipment, note that all void areas behind the insulation blanket are to be filled. The total required thickness of insulation shall not be achieved by including a loose wrap of woven glass fiber felt or refractory fiber blanket as part of the required thickness.

## 9. Requirements for Thermal Insulating Tape

9.1 *Thermal Insulating Tape*—Is capable of being applied to pipe, sizes ¼ in. (8 mm) to ¾ in. (20 mm), for temperatures between 125 and 150°F (52 and 66°C) using materials specified in Section 8 and to thicknesses specified in Table 14. For manufacturing and installation details, see Fig. 6.

9.2 *Filler Materials for Thermal Insulating Tape*—See 8.2.

9.3 *Covering or Encapsulating Materials for Thermal Insulating Tape*:

9.3.1 For surface temperatures below 220°F (105°C), the entire outside surface shall be encapsulated with fiberglass cloth, conforming with MIL-C-20079, Type I, Class 3.

9.3.2 For surface temperatures 220 to 450°F (105 to 232°C), the entire outside surface shall be encapsulated with fiberglass cloth, conforming with MIL-C-20079, Type I, Class 9.

9.3.3 For surface temperatures above 450°F (232°C), the entire outside surface shall be encapsulated with fiberglass cloth, conforming with MIL-C-20079, Type I, Class 9, with an inner jacket of TY304 stainless steel wire mesh, 0.008-in. (0.21-mm) diameter, No. 60 density and crimped. Alternatively, the entire outside surface shall be encapsulated with fiberglass cloth, inserted with stainless steel wire reinforcement, in accordance with HH-P-31, Type I, Class 1.

9.4 *Hardware and Accessory Items for Thermal Insulating Construction*—See 8.5.

9.5 *Special Conditions*—See 8.6.

## 10. Keywords

10.1 insulation; lagging; machinery insulation; marine; piping insulation; ship; shipboard insulation; thermal insulation; vessel