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USACE / NAVFAC / AFCESA / NASA **UFGS-15080 (May 2005)**

Preparing Activity: USACE **MasterFormat™ 2004 - 22 07 09**
Superseding
UFGS-15080 (January 2005)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 23 June 2005

Latest change indicated by CHG tags
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DIVISION 15 - MECHANICAL

SECTION 15080

THERMAL INSULATION FOR MECHANICAL SYSTEMS

05/05

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SECTION 15080

THERMAL INSULATION FOR MECHANICAL SYSTEMS
05/05

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NOTE: This guide specification covers the requirements for field applied thermal insulation on HVAC and plumbing systems located within, on, under, and adjacent to buildings; above and below ground.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.

This guide specification includes tailoring options for pipe insulation, duct insulation, and equipment insulation. Selection or deselection of a tailoring option will include or exclude that option in the section, but editing the resulting section to fit the project is still required.
****

PART 1 GENERAL

****
NOTE: The following information will be shown on project drawings:

1. Areas where pipe insulation differs from the "Typical;"

2. Areas where ductwork is to be internally insulated;

3. Areas where metal jackets are to be used on interior piping;

4. Pumps to be insulated and encased in 20 gauge boxes; and

5. Heat exchange temperatures.

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1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only. At the discretion of the Government, the manufacturer of any material supplied will be required to furnish test reports pertaining to any of the tests necessary to assure compliance with the standard or standards referenced in this specification.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE 90.1	(2001; various Errata) Energy Standard for Buildings Except Low-Rise Residential Buildings
ASHRAE 90.2	(2001) Energy Efficient Design of Low-Rise Residential Buildings

ASTM INTERNATIONAL (ASTM)

ASTM A 167	(2004) Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
ASTM A 240/A 240M	(2004ae1) Chromium and Chromium-Nickel

	Stainless Steel Plate, Sheet, and Strip for Pressure Vessels for General Applications
ASTM A 580/A 580M	(1998; R 2004) Stainless Steel Wire
ASTM B 209	(2004) Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B 209M	(2004) Aluminum and Aluminum-Alloy Sheet and Plate (Metric)
ASTM C 1126	(2004) Faced or Unfaced Rigid Cellular Phenolic Thermal Insulation
ASTM C 1136	(2003a) Flexible, Low Permeance Vapor Retarders for Thermal Insulation
ASTM C 1290	(2004) Flexible Fibrous Glass Blanket Insulation Used to Externally Insulate HVAC Ducts
ASTM C 195	(2000) Mineral Fiber Thermal Insulating Cement
ASTM C 449/C 449M	(2000) Mineral Fiber Hydraulic-Setting Thermal Insulating and Finishing Cement
ASTM C 533	(2004) Calcium Silicate Block and Pipe Thermal Insulation
ASTM C 534	(2003) Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form
ASTM C 547	(2003) Mineral Fiber Pipe Insulation
ASTM C 552	(2003) Cellular Glass Thermal Insulation
ASTM C 553	(2002) Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
ASTM C 591	(2001) Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation
ASTM C 592	(2004) Mineral Fiber Blanket Insulation and Blanket-Type Pipe Insulation (Metal-Mesh Covered) (Industrial Type)
ASTM C 610	(1999) Molded Expanded Perlite Block and Pipe Thermal Insulation
ASTM C 612	(2004) Mineral Fiber Block and Board Thermal Insulation
ASTM C 647	(1995; R 2000) Properties and Tests of Mastics and Coating Finishes for Thermal Insulation

ASTM C 665	(2001e1) Mineral-Fiber Blanket Thermal Insulation for Light Frame Construction and Manufactured Housing
ASTM C 795	(2003) Thermal Insulation for Use in Contact with Austenitic Stainless Steel
ASTM C 916	(1985; R 2001e1) Adhesives for Duct Thermal Insulation
ASTM C 920	(2005) Elastomeric Joint Sealants
ASTM C 921	(2003a) Jackets for Thermal Insulation
ASTM D 882	(2002) Tensile Properties of Thin Plastic Sheeting
ASTM E 2231	(2002) Specimen Preparation and Mounting of Pipe and Duct Insulation Materials to Assess Surface Burning Characteristics
ASTM E 84	(2004) Surface Burning Characteristics of Building Materials
ASTM E 96	(2000e1) Water Vapor Transmission of Materials

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-69	(2002) Pipe Hangers and Supports - Selection and Application

MIDWEST INSULATION ContractorRS ASSOCIATION (MICA)

MICA Insulation Stds	(1999) National Commercial & Industrial Insulation Standards

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 255	(2000) Method of Test of Surface Burning Characteristics of Building Materials
NFPA 96	(2001) Ventilation Control and Fire Protection of Commercial Cooking Operations

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-A-3316	(Rev C; Am 2) Adhesives, Fire-Resistant, Thermal Insulation

UNDERWRITERS LABORATORIES (UL)

UL 723	(2003) Test for Surface Burning Characteristics of Building Materials

1.2 SYSTEM DESCRIPTION

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NOTE: This guide specification is to be used for field applied insulation on mechanical systems; interior and exterior, above and below ground. Insulation for energy distribution systems covered by Section 02546 PRE-ENGINEERED UNDERGROUND HEAT DISTRIBUTION SYSTEM, Section 02547 HEAT DISTRIBUTION SYSTEMS IN CONCRETE TRENCHES, Section 02549 PREFABRICATED UNDERGROUND HEATING/COOLING DISTRIBUTION SYSTEM, and Section 02548 ABOVEGROUND HEAT DISTRIBUTION SYSTEM, are not within the scope of this guide specification. Heating, air conditioning, and evaporative cooling duct; equipment; and piping are included.

Pipe insulation covered in this specification is valid for between minus 34 and plus 204 degrees C (minus 30 and plus 400 degrees F). Equipment insulation covered in this specification is valid for between minus 34 and plus 982 degrees C (minus 30 and plus 1800 degrees F).

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Field-applied insulation and accessories on mechanical systems shall be as specified herein; factory-applied insulation is specified under the piping, duct or equipment to be insulated. Insulation of heat distribution systems and chilled water systems outside of buildings shall be as specified in Section 02546 PRE-ENGINEERED UNDERGROUND HEAT DISTRIBUTION SYSTEM, Section 02547 HEAT DISTRIBUTION SYSTEMS IN CONCRETE TRENCHES, Section 02548 ABOVEGROUND HEAT DISTRIBUTION SYSTEM, and Section 02549 PREFABRICATED UNDERGROUND HEATING/COOLING DISTRIBUTION SYSTEM. Field applied insulation materials required for use on Government-furnished items as listed in the SPECIAL CONTRACT REQUIREMENTS shall be furnished and installed by the Contractor.

1.3 GENERAL QUALITY CONTROL

1.3.1 Standard Products

Provide field-applied insulation for heating, ventilating, and cooling (HVAC) air distribution systems and piping systems which are located within, on, under, and adjacent to buildings; and for plumbing systems. Materials shall be the standard products of manufacturers regularly engaged in the manufacture of such products and shall essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening.

1.3.2 Installer's Qualifications

Qualified installers shall have successfully completed three or more similar type jobs within the last 5 years.

1.3.3 Surface Burning Characteristics

Unless otherwise specified, insulation shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E 84. Flame spread, and smoke developed indexes,

shall be determined by ASTM E 84, NFPA 255 or UL 723. Insulation shall be tested in the same density and installed thickness as the material to be used in the actual construction. Test specimens shall be prepared and mounted according to ASTM E 2231. Insulation materials located exterior to the building perimeter are not required to be fire rated.

1.3.4 Identification of Materials

Packages or standard containers of insulation, jacket material, cements, adhesives, and coatings delivered for use, and samples required for approval shall have manufacturer's stamp or label attached giving the name of the manufacturer and brand, and a description of the material. Insulation packages and containers shall be asbestos free.

1.4 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01330 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.
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NOTE: SD-04 - Designer will exclude ductwork insulation display samples for small, simple projects where the extent of duct insulation is not likely to cause a problem of enforcement with the requirements of the specification.
****
Government approval is required for submittals with a "G" designation;

submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Mica Plates[; G][; G, [_____]]

After approval of materials and prior to applying insulation, a booklet shall be prepared and submitted for approval. The booklet shall contain marked-up MICA Insulation Stds plates (or detail drawings showing the insulation material and insulating system) for each pipe, duct, or piece of equipment that must be insulated per this specification. The MICA plates shall be marked up showing the materials to be installed in accordance with the requirements of this specification for the specific insulation application. The Contractor shall submit all MICA Plates required to show the entire insulating system, including Plates required to show insulation penetrations, vessel bottom and top heads, legs, and skirt insulation as applicable. If the Contractor elects to submit detailed drawings instead of marked-up MICA Plates, the detail drawings shall show cut-away, section views, and details indicating each component of the insulation system and showing provisions for insulating jacketing, and sealing portions of the equipment. For each type of insulation installation on the drawings, provide a label that identifies each component in the installation (i.e., the duct, insulation, adhesive, vapor retarder, jacketing, tape, mechanical fasteners, etc.) Indicate insulation by type and manufacturer. Three copies of the booklet shall be submitted at the jobsite to the Contracting Officer. One copy of the approved booklet shall remain with the insulation Contractor's display sample and two copies shall be provided for Government use.

SD-03 Product Data

General Materials
Adhesives
Sealants
Duct Insulation
Duct Insulation Jackets
Pipe Insulation Materials
Jackets

A complete list of materials, including manufacturer's descriptive technical literature, performance data, catalog cuts, and installation instructions. The product number, k-value, thickness and furnished accessories for each mechanical system requiring insulation shall be included. Materials furnished under this section of the specification shall be submitted at one time.

SD-04 Samples

Thermal Insulation[; G][; G, [_____]]

After approval of materials, actual sections of installed systems, properly insulated in accordance with the specification

requirements, shall be displayed. Such actual sections must remain accessible to inspection throughout the job and will be reviewed from time to time for controlling the quality of the work throughout the construction site. Each material used shall be identified, by indicating on an attached sheet the specification requirement for the material and the material by each manufacturer intended to meet the requirement. The Contracting Officer will inspect display sample sections at the jobsite. Approved display sample sections shall remain on display at the jobsite during the construction period. Upon completion of construction, the display sample sections will be closed and sealed.

Pipe Insulation Display Sections: Display sample sections shall include as a minimum an elbow or tee, a valve, dielectric waterways and flanges, a hanger with protection shield and insulation insert, or dowel as required, at support point, method of fastening and sealing insulation at longitudinal lap, circumferential lap, butt joints at fittings and on pipe runs, and terminating points for each type of pipe insulation used on the job, and for hot pipelines and cold pipelines, both interior and exterior, even when the same type of insulation is used for these services.

Duct Insulation Display Sections: Display sample sections for rigid and flexible duct insulation used on the job. A temporary covering shall be used to enclose and protect display sections for duct insulation exposed to weather.

1.5 STORAGE

Materials shall be delivered in the manufacturer's unopened containers. Materials delivered and placed in storage shall be provided with protection from weather, humidity, dirt, dust and other contaminants. The Contracting Officer may reject insulation material and supplies that become dirty, dusty, wet, or contaminated by some other means.

1.6 RECYCLED MATERIALS

Provide thermal insulation containing recycled materials to the extent practicable, provided that the materials meets all other requirements of this section. The minimum recycled material content of the following insulation are:

Rock Wool - 75 percent slag of weight
Fiberglass - 20-25 percent glass cullet by weight
Rigid Foam - 9 percent recovered material

PART 2 PRODUCTS

2.1 GENERAL MATERIALS

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NOTE: Tables 1, 2, 3, 4, and 5 are not inclusive of systems requiring insulation. Edit, modify, and add to the information contained in tables as required for your project requiring insulation. These tables shall become a part of project specification.

Where the temperature of cold water entering a

building is below average dew point of the indoor ambient air and where condensate drip will cause damage or create a hazard, insulate piping with vapor barrier to prevent condensation, regardless to whether piping is above or below ceilings.

Cellular glass and faced rigid cellular phenolic foam are very suitable for chilled water applications. Minimum thickness recommended for cellular glass insulation is 40 mm (1.5 inches). The reason is that the breakage rate during shipment of 25 mm (one inch) thick cellular insulation is too high to be economical. For faced rigid cellular phenolic foam, recommended minimum thickness is 25 mm (one inch).

For cryogenic equipment handling media between minus 34 and minus 18 degrees C (30 and minus one degree F), use cellular glass or faced rigid cellular phenolic foam insulation.

Table 7 is primarily used for personnel safety where stacks or pipes are within reach, or if stacks or pipes run through conditioned spaces where heat losses may increase building energy usage.

ASHRAE 90.2 is for low-rise building. ASHRAE 90.1 is for high-rise building. Low-rise building has one or two stories without elevators. High-rise building has multistory with elevators.

For LANTNAVFACENGCOM projects, delete the option of 13 mm (1/2 inch) from line 4 of the following paragraph.
****

Insulation material shall conform to Table 1. Insulation thickness shall be as listed in Table 2. Insulation thickness as specified in Table 2 shall be [13] [25] mm [1/2] [1] inch. [In lieu of Table 2, minimum thickness may be calculated in accordance with [Table 2A excerpted from ASHRAE 90.2] [ASHRAE 90.1, Section 9, Table 9-1 and Equation 9-1].] Insulation exterior shall be cleanable, grease resistant, non-flaking and non-peeling. Materials shall be compatible and shall not contribute to corrosion, soften, or otherwise attack surfaces to which applied in either wet or dry state. Materials to be used on stainless steel surfaces shall meet ASTM C 795 requirements. Materials shall be asbestos free and conform to the following:

2.1.1 Adhesives

2.1.1.1 Acoustical Lining Insulation Adhesive

Adhesive shall be a nonflammable, fire-resistant adhesive conforming to ASTM C 916, Type I.

2.1.1.2 Mineral Fiber Insulation Cement

Cement shall be in accordance with ASTM C 195.

2.1.1.3 Lagging Adhesive

Lagging is the material used for thermal insulation, especially around a cylindrical object. This may include the insulation as well as the cloth/material covering the insulation. Lagging adhesives shall be nonflammable and fire-resistant and shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E 84. Adhesive shall be MIL-A-3316, Class 1, pigmented [white] [red] and be suitable for bonding fibrous glass cloth to faced and unfaced fibrous glass insulation board; for bonding cotton brattice cloth to faced and unfaced fibrous glass insulation board; for sealing edges of and bonding fibrous glass tape to joints of fibrous glass board; for bonding lagging cloth to thermal insulation; or Class 2 for attaching fibrous glass insulation to metal surfaces. Lagging adhesives shall be applied in strict accordance with the manufacturer's recommendations for pipe and duct insulation.

2.1.2 Contact Adhesive

Adhesives may be any of, but not limited to, the neoprane based, rubber based, or elastomeric type that have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E 84. The adhesive shall not adversely affect, initially or in service, the insulation to which it is applied, nor shall it cause any corrosive effect on metal to which it is applied. Any solvent dispersing medium or volatile component of the adhesive shall have no objectionable odor and shall not contain any benzene or carbon tetrachloride. The dried adhesive shall not emit nauseous, irritating, or toxic volatile matters or aerosols when the adhesive is heated to any temperature up to 100 degrees C 212 degrees F. The dried adhesive shall be nonflammable and fire resistant. Natural cross-ventilation, local (mechanical) pickup, and/or general area (mechanical) ventilation shall be used to prevent an accumulation of solvent vapors, keeping in mind the ventilation pattern must remove any heavier-than-air solvent vapors from lower levels of the workspaces. Gloves and spectacle-type safety glasses are recommended in accordance with safe installation practices.

2.1.3 Caulking

ASTM C 920, Type S, Grade NS, Class 25, Use A.

2.1.4 Corner Angles

Nominal 0.4060 mm 0.016 inch aluminum 25 x 25 mm 1 x 1 inch with factory applied kraft backing. Aluminum shall be ASTM B 209M ASTM B 209, Alloy 3003, 3105, or 5005.

2.1.5 Finishing Cement

ASTM C 449/C 449M: Mineral fiber hydraulic-setting thermal insulating and finishing cement. All cements that may come in contact with Austenitic stainless steel must comply with ASTM C 795.

2.1.6 Fibrous Glass Cloth and Glass Tape

Fibrous glass cloth, with 20X20 maximum mesh size, and glass tape shall have maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E 84. Tape shall be 100 mm 4 inch wide rolls. Class 3 tape shall be 0.15 kg/square m 4.5 ounces/square yard.

2.1.7 Staples

****
NOTE: Monel is a nickel rich alloy that has high strength, high ductility, and excellent resistance to corrosion.
****

Outward clinching type [monel] [ASTM A 167, Type 304 or 316 stainless steel].

2.1.8 Jackets

****
NOTE: The purpose of jacketing insulated pipes and vessels is to protect the vapor retarder system and the insulation. Protective jacteting is designed to be installed over the vapor retarder and insulation to prevent weather and abrasion damage. The protective jacteting must be installed independently and in addition to any factory or field applied vapor retarder.
****

2.1.8.1 Aluminum Jackets

Aluminum jackets shall be corrugated, embossed or smooth sheet, 0.4060 mm 0.016 inch nominal thickness; ASTM B 209M ASTM B 209, Temper H14, Temper H16, Alloy 3003, 5005, or 3105 with factory applied moisture retarder. Corrugated aluminum jacket shall not be used outdoors. Aluminum jacket securing bands shall be Type 304 stainless steel, 0.3960 mm 0.015 inch thick, 12.7 mm 1/2 inch wide for pipe under 300 mm 12 inch diameter and 19.1 mm 3/4 inch wide for pipe over 300 mm 12 inch and larger diameter. Aluminum jacket circumferential seam bands shall be 50.8 x 0.4060 mm 2 x 0.016 inch aluminum matching jacket material. Bands for insulation below ground shall be 19.1 x 0.5080 mm 3/4 x 0.020 inch thick stainless steel, or fiberglass reinforced tape. The jacket may, at the option of the Contractor, be provided with a factory fabricated Pittsburg or "Z" type longitudinal joint. When the "Z" joint is used, the bands at the circumferential joints shall be designed by the manufacturer to seal the joints and hold the jacket in place.

2.1.8.2 Polyvinyl Chloride (PVC) Jackets

Polyvinyl chloride (PVC) jacket and fitting covers shall have high impact strength, UV resistant rating or treatment and moderate chemical resistance with minimum thickness 0.7620 mm 0.030 inch.

2.1.9 Vapor Retarder Required

****
NOTE: The functions of a vapor retarder are to keep out water, water vapor, and to prevent water vapor infiltration, in order to keep the insulation dry. Type I is a vapor retarder for use over insulation on pipes, ducts, or equipment operating at temperatures below ambient at least part of the time or wherever a vapor retarder is required. Type II

is water vapor permeable and for use over pipes, ducts, or equipment operating above ambient temperatures or wherever a vapor retarder is not required.

****

ASTM C 921, Type I, minimum puncture resistance 50 Beach units on all surfaces except concealed ductwork, where a minimum puncture resistance of 25 Beach units is acceptable. Minimum tensile strength, 6.1 N/mm 35 pounds/inch width. ASTM C 921, Type II, minimum puncture resistance 25 Beach units, tensile strength minimum 3.5 N/mm 20 pounds/inch width. Jackets used on insulation exposed in finished areas shall have white finish suitable for painting without sizing. Based on the application, insulation materials that require factory applied jackets are mineral fiber, cellular glass, polyisocyanurate, and phenolic foam. Insulation materials that do not require jacketing are flexible elastomerics. All non-metallic jackets shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E 84.

2.1.9.1 White Vapor Retarder All Service Jacket (ASJ)

Standard reinforced fire retardant jacket for use on hot/cold pipes, ducts, or equipment. Vapor retarder jackets used on insulation exposed in finished areas shall have white finish suitable for painting without sizing.

2.1.9.2 Vapor Retarder Mastic Coatings

The vapor retarder coating shall be fire and water resistant and appropriately selected for either outdoor or indoor service. Color shall be white. The water vapor permeance of the compound shall be determined according to procedure B of ASTM E 96 utilizing apparatus described in ASTM E 96. The coating shall be a nonflammable, fire resistant type. All other application and service properties shall be in accordance with ASTM C 647.

2.1.9.3 Laminated Film Vapor Retarder

ASTM C 1136, Type I, maximum moisture vapor transmission 0.02 perms, minimum puncture resistance 50 Beach units on all surfaces except concealed ductwork, where Type II, maximum moisture vapor transmission 0.02 perms, a minimum puncture resistance of 25 Beach units is acceptable. Vapor retarder shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E 84.

2.1.9.4 Polyvinylidene Chloride (PVDC) Film Vapor Retarder

The PVDC film vapor retarder shall have a maximum moisture vapor transmission of 0.02 perms, minimum puncture resistance of 150 Beach units, a minimum tensile strength in any direction of 5.3 kN/m 30 lb/inch when tested per ASTM D 882, and a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E 84.

2.1.9.5 Polyvinylidene Chloride Vapor Retarder Adhesive Tape

Requirements must meet the same as specified for Laminated Film Vapor Retarder above.

2.1.10 Vapor Retarder Not Required

ASTM C 921, Type II, Class D, minimum puncture resistance 50 Beach units on

all surfaces except ductwork, where Type IV, maximum moisture vapor transmission 0.10, a minimum puncture resistance of 25 Beach units is acceptable. Jacket shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E 84.

2.1.11 Wire

Soft annealed ASTM A 580/A 580M Type 302, 304 or 316 stainless steel, 16 or 18 gauge.

2.1.12 Insulation Bands

Insulation bands shall be 15 mm 1/2 inch wide; 26 gauge stainless steel.

2.1.13 Sealants

Sealants shall be chosen from the butyl polymer type, the styrene-butadiene rubber type, or the butyl type of sealants. Sealants shall have a maximum moisture vapor transmission of 0.02 perms, and a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E 84.

2.2 PIPE INSULATION MATERIALS

The Contractor shall comply with EPA requirements in accordance with Section 01670 RECYCLED / RECOVERED MATERIALS. Pipe insulation materials shall be limited to those listed herein and shall meet the following requirements:

2.2.1 Aboveground Cold Pipeline (-34 to 16 degrees C -30 to 60 degrees F)

****

NOTE: When it is necessary to insulate an existing cold water system that must remain in operation, the Designer may consider using a mineral fiber insulation that meets ASTM C 547, with an integral wicking material designed to remove condensed water.

****

Insulation for outdoor, indoor, exposed or concealed applications, shall be as follows:

a. Cellular Glass: ASTM C 552, Type II, and Type III. Supply the insulation with manufacturer's recommended factory-applied jacket.

b. Flexible Elastomeric Cellular Insulation: ASTM C 534, Grade 1, Type I or II. Type II shall have vapor retarder skin on one or both sides of the insulation.

c. Phenolic Insulation: ASTM C 1126, Type III. Phenolic insulations shall comply with ASTM C 795 and with the ASTM C 665 paragraph Corrosiveness. Supply the insulation with manufacturer's recommended factory-applied jacket.

d. Polyisocyanurate Insulation: ASTM C 591, type I. Supply the insulation with manufacturer's recommended factory-applied vapor retarder.

2.2.2 Aboveground Hot Pipeline (Above 16 degrees C 60 degrees F)

Insulation for outdoor, indoor, exposed or concealed applications shall meet the following requirements. Supply the insulation with manufacturer's recommended factory-applied jacket.

a. Mineral Fiber: ASTM C 547, Types I, II or III, supply the insulation with manufacturer's recommended factory-applied jacket.

b. Calcium Silicate: ASTM C 533, Type I indoor only, or outdoors above 121 degrees C 250 degrees F pipe temperature. Supply insulation with the manufacturer's recommended factory-applied jacket.

c. Cellular Glass: ASTM C 552, Type II and Type III. Supply the insulation with manufacturer's recommended factory-applied jacket.

d. Flexible Elastomeric Cellular Insulation: ASTM C 534, Grade 1, Type I or II to 93 degrees C 200 degrees F service.

e. Phenolic Insulation: ASTM C 1126 Type III to 121 C 250 F service shall comply with ASTM C 795. Supply the insulation with manufacturer's recommended factory-applied jacket.

f. Perlite Insulation: ASTM C 610

g. Polyisocyanurate Insulation: ASTM C 591, Type 1, to 149 degrees C 300 degrees F service. Supply the insulation with manufacturer's recommended factory applied jacket.

2.2.3 Above Ground Dual Temperature Pipeline - Outdoors, Indoor - Exposed or Concealed

****

NOTE: The use of multiple layered systems, i.e., a flexible form of insulation, surrounded by a rigid form and sealed with mastics, sealants and vapor retarders, may provide the most advantageous form of insulation system for this piping configuration. This is due to the pipe expansion and contraction associated with the change from hot to cold temperatures.

****

Selection of insulation for use over a dual temperature pipeline system shall be in accordance with the most limiting/restrictive case. Find an allowable material from paragraph PIPE INSULATION MATERIALS and determine the required thickness from the most restrictive case. Use the thickness listed in paragraphs INSULATION THICKNESS for cold & hot pipe applications.

2.2.4 Below-ground Pipeline Insulation

For below-ground pipeline insulation the following requirements shall be met.

2.2.4.1 Cellular Glass

ASTM C 552, type II.

2.2.4.2 Polyisocyanurate

ASTM C 591, Type 1, to 149 degrees C 300 degrees F.

2.3 DUCT SYSTEMS INSULATION

****
NOTE: For NORTHNAVFACENGCOM projects, delete option of the following paragraph.
****

2.3.1 Duct Insulation

Provide factory-applied [cellular glass polyisocyanurate or phenolic foam] insulation with insulation manufacturer's standard reinforced fire-retardant vapor barrier[, with identification of installed thermal resistance (R) value and out-of-package R value.]

2.3.1.1 Rigid Insulation

Rigid mineral fiber in accordance with ASTM C 612, Class 2 (maximum surface temperature 204 degrees C 400 degrees F), 48 kg/m3 3 pcf average, 25 mm one inch thick, Type IA, IB, II, III, and IV. [Alternately, minimum thickness may be calculated in accordance with [ASHRAE 90.2] [ASHRAE 90.1].]

2.3.1.2 Blanket Insulation

****
NOTE: For NORTHNAVFACENGCOM, delete this paragraph.
****

Blanket flexible mineral fiber insulation conforming to ASTM C 553, Type 1, Class B-3, 12 kg/m3 3/4 pcf nominal, 50 mm 2.0 inches thick or Type II up to 121 degrees C 250 degrees F. Also ASTM C 1290 Type III may be used. [Alternately, minimum thickness may be calculated in accordance with [ASHRAE 90.2] [ASHRAE 90.1].]

2.3.2 Kitchen Exhaust Ductwork Insulation

****
NOTE: If kitchen exhaust hood has outside air connection to cold outdoor, provide vapor barrier for outside air connection to prevent dissolution of calcium silicate.
****

Minimum insulation thickness of 50 mm 2 inches, blocks or boards, either mineral fiber conforming to ASTM C 612, Class 5, 320 kg/m3 20 pcf average [or calcium silicate conforming to ASTM C 533, Type II. Provide vapor barrier for outside air connection to kitchen exhaust hood].

2.3.3 Acoustical Duct Lining

For ductwork indicated or specified in Section [15895 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM] [15810N DUCTWORK AND DUCTWORK ACCESSORIES] to be acoustically lined, provide external insulation in accordance with this specification section and in addition to the acoustical duct lining.

2.3.4 Duct Insulation Jackets

2.3.4.1 All-Purpose Jacket

Provide insulation with insulation manufacturer's standard reinforced fire-retardant jacket with or without integral vapor barrier as required by the service. In exposed locations, provide jacket with a white surface suitable for field painting.

2.3.4.2 Metal Jackets

a. Aluminum Jackets: ASTM B 209M ASTM B 209, Temper H14, minimum thickness of 27 gauge (0.41 mm 0.016 inch), with factory-applied polyethylene and kraft paper moisture barrier on inside surface. Provide smooth surface jackets for jacket outside dimension 200 mm 8 inches and larger. Provide corrugated surface jackets for jacket outside dimension 200 mm 8 inches and larger. Provide stainless steel bands, minimum width of 15 mm 0.5 inch.

b. Stainless Steel Jackets: ASTM A 167 or ASTM A 240/A 240M; Type 304, minimum thickness of 33 gauge (0.25 mm 0.010 inch), smooth surface with factory-applied polyethylene and kraft paper moisture barrier on inside surface. Provide stainless steel bands, minimum width of 15 mm 0.5 inch.

2.3.5 Weatherproof Duct Insulation

Provide [ASTM C 591 Type I, polyurethane or polyisocyanate board insulation, minimum density of 27 kg/m3 1.7 pcf] [ASTM C 534 Grade 1, Type II, flexible cellular insulation], and weatherproofing as specified in manufacturer's instruction.

2.4 EQUIPMENT INSULATION MATERIALS

Insulate equipment and accessories as specified in Tables 4 and 5. In outside locations, provide insulation 15 mm 1/2 inch thicker than specified. Increase the specified insulation thickness for equipment where necessary to equal the thickness of angles or other structural members to make a smooth, exterior surface.

PART 3 EXECUTION

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NOTE: Project specifications will contain only the specific pipe or duct systems and equipment in a particular project that require insulation. Lists are not inclusive of systems requiring insulation. Edit, modify, and add to the information contained in the lists as required.

****

3.1 APPLICATION - GENERAL

Insulation shall only be applied to unheated and uncooled piping and equipment. Flexible elastomeric cellular insulation shall not be compressed at joists, studs, columns, ducts, hangers, etc. The insulation shall not pull apart after a one hour period; any insulation found to pull apart after one hour, shall be replaced.

3.1.1 Installation

Except as otherwise specified, material shall be installed in accordance with the manufacturer's written instructions. Insulation materials shall not be applied until [tests] [tests and heat tracing] specified in other sections of this specification are completed. Material such as rust, scale, dirt and moisture shall be removed from surfaces to receive insulation. Insulation shall be kept clean and dry. Insulation shall not be removed from its shipping containers until the day it is ready to use and shall be returned to like containers or equally protected from dirt and moisture at the end of each workday. Insulation that becomes dirty shall be thoroughly cleaned prior to use. If insulation becomes wet or if cleaning does not restore the surfaces to like new condition, the insulation will be rejected, and shall be immediately removed from the jobsite. Joints shall be staggered on multi layer insulation. Mineral fiber thermal insulating cement shall be mixed with demineralized water when used on stainless steel surfaces. Insulation, jacketing and accessories shall be installed in accordance with MICA Insulation Stds plates except where modified herein or on the drawings.

3.1.2 Firestopping

Where pipes and ducts pass through fire walls, fire partitions, above grade floors, and fire rated chase walls, the penetration shall be sealed with fire stopping materials as specified in Section 07840 FIRESTOPPING.

3.1.3 Painting and Finishing

Painting shall be as specified in Section 09900 PAINTS AND COATINGS.

3.1.4 Installation of Flexible Elastomeric Cellular Insulation

Flexible elastomeric cellular insulation shall be installed with seams and joints sealed with rubberized contact adhesive. Insulation with pre-applied adhesive is not permitted. Flexible elastomeric cellular insulation shall not be used on surfaces greater than 93 degrees C 200 degrees F. Seams shall be staggered when applying multiple layers of insulation. Insulation exposed to weather and not shown to have jacketing shall be protected with two coats of UV resistant finish or PVC or metal jacketing as recommended by the manufacturer after the adhesive is dry and cured. A brush coating of adhesive shall be applied to both butt ends to be joined and to both slit surfaces to be sealed. The adhesive shall be allowed to set until dry to touch but tacky under slight pressure before joining the surfaces. Insulation seals at seams and joints shall not be capable of being pulled apart one hour after application. Insulation that can be pulled apart one hour after installation shall be replaced.

3.1.5 Welding

No welding shall be done on piping, duct or equipment without written approval of the Contracting Officer. The capacitor discharge welding process may be used for securing metal fasteners to duct.

3.1.6 Pipes/Ducts/Equipment which Require Insulation

Insulation is required on all pipes, ducts, or equipment, except for omitted items, as specified.

3.2 PIPE INSULATION INSTALLATION

3.2.1 Pipe Insulation

3.2.1.1 General

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NOTE: Insulation may be omitted on heating piping in heated spaces, and on domestic cold water piping and interior roof drains where condensation and freezing are not problems and where hot piping is not hazardous to the occupants. However, the designer must maintain environmental control under heating and cooling conditions, meet the energy budget, not allow condensate formation and not allow freezing.

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Pipe insulation shall be installed on aboveground hot and cold pipeline systems as specified below to form a continuous thermal retarder, including straight runs, fittings and appurtenances unless specified otherwise. Installation shall be with full length units of insulation and using a single cut piece to complete a run. Cut pieces or scraps abutting each other shall not be used. Pipe insulation shall be omitted on the following:

a. Pipe used solely for fire protection.

b. Chromium plated pipe to plumbing fixtures. However, fixtures for use by the physically handicapped shall have the hot water supply and drain, including the trap, insulated where exposed.

c. Sanitary drain lines.

d. Air chambers.

e. Adjacent insulation.

f. ASME stamps.

g. Access plates of fan housings.

h. Cleanouts or handholes.

i. Components within factory preinsulated HVAC equipment.

j. Factory preinsulated flexible ductwork.

k. Factory preinsulated HVAC equipment.

l. Manufacturer's nameplates.

m. Vibration isolating connections.

3.2.1.2 Pipes Passing Through Walls, Roofs, and Floors

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NOTE: Exterior wall and roof penetration details will be shown on the drawings. See Section 15400 PLUMBING, GENERAL PURPOSE for additional information.

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a. Pipe insulation shall be continuous through the sleeve.

b. An aluminum jacket with factory applied moisture retarder shall be provided over the insulation wherever penetrations require sealing.

c. Where pipes penetrate interior walls, the aluminum jacket shall extend 50 mm 2 inches beyond either side of the wall and shall be secured on each end with a band.

d. Where penetrating floors, the aluminum jacket shall extend from a point below the backup material to a point 250 mm 10 inches above the floor with one band at the floor and one not more than 25 mm 1 inch from the end of the aluminum jacket.

e. Where penetrating waterproofed floors, the aluminum jacket shall extend from below the backup material to a point 50 mm 2 inches above the flashing with a band 25 mm 1 inch from the end of the aluminum jacket.

f. Where penetrating exterior walls, the aluminum jacket required for pipe exposed to weather shall continue through the sleeve to a point 50 mm 2 inches beyond the interior surface of the wall.

g. Where penetrating roofs, pipe shall be insulated as required for interior service to a point flush with the top of the flashing and sealed with vapor retarder coating. The insulation for exterior application shall butt tightly to the top of flashing and interior insulation. The exterior aluminum jacket shall extend 50 mm 2 inches down beyond the end of the insulation to form a counter flashing. The flashing and counter flashing shall be sealed underneath with caulking.

h. For hot water pipes supplying lavatories or other similar heated service that requires insulation, the insulation shall be terminated on the backside of the finished wall. The insulation termination shall be protected with two coats of vapor barrier coating with a minimum total thickness of 2.0 mm 1/16 inch applied with glass tape embedded between coats (if applicable). The coating shall extend out onto the insulation 50.0 mm 2 inches and shall seal the end of the insulation. Glass tape seams shall overlap 25 mm 1 inch. The annular space between the pipe and wall penetration shall be caulked with approved fire stop material. The pipe and wall penetration shall be covered with a properly sized (well fitting) escutcheon plate. The escutcheon plate shall overlap the wall penetration at least 10 mm 3/8 inches.

i. For domestic cold water pipes supplying lavatories or other similar cooling service that requires insulation, the insulation shall be terminated on the finished side of the wall (i.e., insulation must cover the pipe throughout the wall penetration). The insulation shall be protected with two coats of vapor barrier coating with a minimum total thickness of 2.0 mm 1/16 inch. The coating shall extend out onto the insulation 50 mm 2 inches and shall seal the end of the insulation. The annular space between the outer surface of the pipe insulation and the wall penetration shall be caulked with an approved fire stop material having vapor retarder properties. The pipe and wall penetration shall be

covered with a properly sized (well fitting) escutcheon plate. The escutcheon plate shall overlap the wall penetration by at least 10 mm 3/8 inches.

3.2.1.3 Pipes Passing Through Hangers

a. Insulation, whether hot or cold application, shall be continuous through hangers. All horizontal pipes 50 mm 2 inches and smaller shall be supported on hangers with the addition of a Type 40 protection shield to protect the insulation in accordance with MSS SP-69. Whenever insulation shows signs of being compressed, or when the insulation or jacket shows visible signs of distortion at or near the support shield, insulation inserts as specified below for piping larger than 50 mm 2 inches shall be installed.

b. Horizontal pipes larger than 50 mm 2 inches at 16 degrees C 60 degrees F and above shall be supported on hangers in accordance with MSS SP-69, and Section 15400 PLUMBING, GENERAL PURPOSE .

c. Horizontal pipes larger than 50 mm 2 inches and below 16 degrees C 60 degrees F shall be supported on hangers with the addition of a Type 40 protection shield in accordance with MSS SP-69. An insulation insert of cellular glass, calcium silicate (or perlite above 27 C 80 F), or the necessary strength polyisocyanurate shall be installed above each shield. The insert shall cover not less than the bottom 180-degree arc of the pipe. Inserts shall be the same thickness as the insulation, and shall extend 50 mm 2 inches on each end beyond the protection shield. When insulation inserts are required per the above, and the insulation thickness is less than 25 mm 1 inch, wooden or cork dowels or blocks may be installed between the pipe and the shield to prevent the weight of the pipe from crushing the insulation, as an option to installing insulation inserts. The insulation jacket shall be continuous over the wooden dowel, wooden block, or insulation insert.

d. Vertical pipes shall be supported with either Type 8 or Type 42 riser clamps with the addition of two Type 40 protection shields in accordance with MSS SP-69 covering the 360-degree arc of the insulation. An insulation insert of cellular glass or calcium silicate shall be installed between each shield and the pipe. The insert shall cover the 360-degree arc of the pipe. Inserts shall be the same thickness as the insulation, and shall extend 50 mm 2 inches on each end beyond the protection shield. When insulation inserts are required per the above, and the insulation thickness is less than 25 mm 1 inch, wooden or cork dowels or blocks may be installed between the pipe and the shield to prevent the hanger from crushing the insulation, as an option instead of installing insulation inserts. The insulation jacket shall be continuous over the wooden dowel, wooden block, or insulation insert. The vertical weight of the pipe shall be supported with hangers located in a horizontal section of the pipe. When the pipe riser is longer than 9 m 30 feet, the weight of the pipe shall be additionally supported with hangers in the vertical run of the pipe that are directly clamped to the pipe, penetrating the pipe insulation. These hangers shall be insulated and the insulation jacket sealed as indicated herein for anchors in a similar service.

e. Inserts shall be covered with a jacket material of the same appearance and quality as the adjoining pipe insulation jacket,

shall overlap the adjoining pipe jacket 38 mm 1-1/2 inches, and shall be sealed as required for the pipe jacket. The jacket material used to cover inserts in flexible elastomeric cellular insulation shall conform to ASTM C 1136, Type 1, and is allowed to be of a different material than the adjoining insulation material.

3.2.1.4 Flexible Elastomeric Cellular Pipe Insulation

Flexible elastomeric cellular pipe insulation shall be tubular form for pipe sizes 150 mm 6 inches and less. Grade 1, Type II sheet insulation used on pipes larger than 150 mm 6 inches shall not be stretched around the pipe. On pipes larger than 300 mm 12 inches, the insulation shall be adhered directly to the pipe on the lower 1/3 of the pipe. Seams shall be staggered when applying multiple layers of insulation. Sweat fittings shall be insulated with miter-cut pieces the same size as on adjacent piping. Screwed fittings shall be insulated with sleeved fitting covers fabricated from miter-cut pieces and shall be overlapped and sealed to the adjacent pipe insulation.

3.2.1.5 Pipes in high abuse areas.

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NOTE: In high abuse areas such as janitor closets and traffic areas in equipment rooms and kitchens, aluminum jackets will be shown. Normally, pipe insulation to the 1.8 m (6 feet) level will be protected in high abuse areas. The designer will specifically indicate the high abuse areas.

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In high abuse areas such as janitor closets and traffic areas in equipment rooms, kitchens, and mechanical rooms, [welded PVC] [stainless steel] [aluminum] jackets shall be utilized. Pipe insulation to the 1.8 m 6 foot level shall be protected. [Other areas that specifically require protection to the 1.8 m 6 foot level are [_____].]

3.2.1.6 Pipe Insulation Material and Thickness

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NOTE: Where the temperature of cold water entering a building is below average dew point of the indoor ambient air and where condensate drip will cause damage or create a hazard, insulate piping with vapor barrier to prevent condensation, regardless to whether piping is above or below ceilings.

Cellular glass and faced rigid cellular phenolic foam are very suitable for chilled water applications. Minimum thickness recommended for cellular glass insulation is 40 mm (1.5 inches). The reason is that the breakage rate during shipment of 25 mm (one inch) thick cellular insulation is too high to be economical. For faced rigid cellular phenolic foam, recommended minimum thickness is 25 mm (one inch).

For cryogenic equipment handling media between minus 34 and minus 18 degrees C (30 and minus one degree F), use cellular glass or faced rigid cellular

phenolic foam insulation.

In Tables 1 and 3, state if a vapor barrier is required. Pipes and equipment with a temperature below 27 degrees C (80 degrees F) should generally be provided with a vapor barrier jacket to prevent sweating. However, engineering judgment should be exercised to determine if a vapor barrier jacket is required.

For LANTNAVFACENGCOM projects, delete "Type" and "Class" in its entirety from Table 1; delete "Flexible Cellular" from material column of Tables 1 and 2 except refrigerant suction piping; and provide vapor barriers for all services. Delete data from High Temperature Hot Water and Brine Systems.

For SOUTHNAVFACENGCOM projects, use only cellular glass with vapor barrier for chilled water piping.

****

TABLE 1
Insulation Material For Piping (°C)

Service	Material	Spec.	Type	Class	Vapor Retarder Required
Chilled Water (Supply & Return, Dual Temperature Piping, 4.44°C nominal)	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Polyisocianurate	ASTM C 591	I		Yes
Heating Hot Water Supply & Return, Heated Oil (Max 121°C)	Mineral Fiber	ASTM C 547	I	1	No
	Calcium Silicate	ASTM C 533	I		No
	Cellular Glass	ASTM C 552	II	2	No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Perlite	ASTM C 610			No
	Polyisocianurate	ASTM C 591	I		No
Cold Domestic Water Piping, Makeup Water & Drinking Fount Drain Piping	Polyisocianurate	ASTM C 591	I		Yes
	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
Hot Domestic Water Supply & Recirculating Piping, Water Defrost Lines (Max 93°C)	Mineral Fiber	ASTM C 547	I	1	No
	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Polyisocianurate	ASTM C 591	I		No
Refrigerant Suction Piping (1.67°C	Flex Elast Cell'r	ASTM C 534	I		No
	Cellular Glass	ASTM C 552	II	1	Yes
	Faced Phenol Foam	ASTM C 1126	III		Yes

TABLE 1
Insulation Material For Piping (°C)

Service	Material	Spec.	Type	Class	Vapor Retarder Required
nominal)	Polyisocianurate	ASTM C 591	I		Yes
Compressed Air Discharge, Steam and Condensate Return (94 to 121°C)	Cellular Glass	ASTM C 552	II		No
	Mineral Fiber	ASTM C 547	I	1	No
	Calcium Silicate	ASTM C 533	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Perlite	ASTM C 610			No
	Polyisocianurate	ASTM C 591	I		No
Exposed Lav'ry Drains, Exposed Domestic Water Piping & Drains to Areas for Handicap Personnel	Flex Elast Cell'r	ASTM C 534	I		No
Horizontal Roof Drain Leaders (Including Underside of Roof Drain Fittings)	Polyisocianurate	ASTM C 591	I		Yes
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Cellular Glass	ASTM C 552	III		Yes
A/C condensate Drain Located Inside Bldg.	Polyisocianurate	ASTM C 591	I		Yes
	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
Medium Temperature Hot Water, Steam and Condensate (122 to 176°C)	Mineral Fiber	ASTM C 547	I	1	No
	Calcium Silicate	ASTM C 533	I		No
	Cellular Glass	ASTM C 552	I or II		No
	Perlite	ASTM C 610			No
	Polyisocianurate	ASTM C 591	I		No
High Temperature Hot Water & Steam (177 to 371°C)	Mineral Fiber	ASTM C 547	I	2	No
	Calcium Silicate	ASTM C 533	I		No
	Perlite	ASTM C 610			No
	Cellular Glass	ASTM C 552			No
	Polyisocianurate	ASTM C 591	I		No
Brine Systems Cryogenics (Minus 34 to Minus 18°C)	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Polyisocianurate	ASTM C 591	I		Yes
Brine Systems Cryogenics (Minus 18 to 1.11°C)	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Polyisocianurate	ASTM C 591	I		Yes

****

NOTE: For LANTNAVFACENGCOM projects, delete "Type" and "Class" in its entirety from Table 1; delete "Flexible Cellular" from material column of Tables 1 and 2 except refrigerant suction piping; and provide vapor barriers for all services. Delete data from High Temperature Hot Water and Brine Systems.

For SOUTHNAVFACENGCOM projects, use only cellular glass with vapor barrier for chilled water piping.

For PACNAVFACENGCOM projects in high humidity (tropical) areas, do not add mineral fiber on chilled water, refrigerant suction, and other cold piping to Table 1.

****

TABLE 1
Insulation Material For Piping (°F)

Service	Material	Spec.	Type	Class	Vapor Retarder Required
Chilled Water (Supply & Return, Dual Temperature Piping, 40°F nominal)	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Polyisocianurate	ASTM C 591	I		Yes
Heating Hot Water Supply & Return, Heated Oil (Max 250°F)	Mineral Fiber	ASTM C 547	I	1	No
	Calcium Silicate	ASTM C 533	I		No
	Cellular Glass	ASTM C 552	II	2	No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Perlite	ASTM C 610			No
	Polyisocianurate	ASTM C 591	I		No
Cold Domestic Water Piping, Makeup Water & Drinking Fount Drain Piping	Polyisocianurate	ASTM C 591	I		Yes
	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
Hot Domestic Water Supply & Recirculating Piping (Max. 200°F)	Mineral Fiber	ASTM C 547	I	1	No
	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Polyisocianurate	ASTM C 591	I		No
Refrigerant Suction Piping (35°F nominal)	Flex Elast Cell'r	ASTM C 534	I		No
	Cellular Glass	ASTM C 552	II	1	Yes
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Polyisocianurate	ASTM C 591	I		Yes
Compressed Air Discharge, Steam and	Cellular Glass	ASTM C 552	II		No
	Mineral Fiber	ASTM C 547	I	1	No
	Calcium Silicate	ASTM C 533	I		No

TABLE 1
Insulation Material For Piping (°F)

Service	Material	Spec.	Type	Class	Vapor Retarder Required
Condensate Return (201 to 250°F)	Faced Phenol Foam	ASTM C 1126	III		Yes
	Perlite	ASTM C 610			No
	Polyisocianurate	ASTM C 591	I		No
Exposed Lav'ry Drains, Exposed Domestic Water Piping & Drains to Areas for Handicap Personnel	Flex Elast Cell'r	ASTM C 534	I		No
Horizontal Roof Drain Leaders (Including Underside of Roof Drain Fittings)	Polyisocianurate	ASTM C 591	I		Yes
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Cellular Glass	ASTM C 552	III		Yes
A/C condensate Drain Located Inside Bldg.	Polyisocianurate	ASTM C 591	I		Yes
	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	II		Yes
Medium Tempera- ture Hot Water, Steam and Condensate (251 to 350°F)	Mineral Fiber	ASTM C 547	I	1	No
	Calcium Silicate	ASTM C 533	I		No
	Cellular Glass	ASTM C 552	I or II		No
	Perlite	ASTM C 610			No
	polyisocianurate	ASTM C 591	I		No
High Tempera- ture Hot Water & Steam (351 to 700°F)	Mineral Fiber	ASTM C 547	I	2	No
	Calcium Silicate	ASTM C 533	I		No
	Perlite	ASTM C 610			No
	Cellular Glass	ASTM C 552			No
	Polyisocianurate	ASTM C 591	I		No
Brine Systems Cryogenics (Minus 30 to 0°F)	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Polyisocianurate	ASTM C 591	I		Yes
Brine Systems Cryogenics (Zero to 34°F)	Cellular Glass	ASTM C 552	II	2	No
	Flex Elast Cell'r	ASTM C 534	I		No
	Faced Phenol Foam	ASTM C 1126	III		Yes
	Polyisocianurate	ASTM C 591	I		Yes

****

NOTE: Table 2 is not inclusive of systems requiring insulation. Edit, modify, and add to the information contained in tables as required for the

project. These tables will become a part of the project specifications. Refer to Table 6-4 of ASHRAE 90.2 for Minimum Pipe Insulation.

Where the temperature of cold water entering a building is below average dew point of the indoor ambient air and where condensate drip will cause damage or create a hazard, insulate piping with vapor barrier to prevent condensation, regardless to whether piping is above or below ceilings.

Cellular glass and faced rigid cellular phenolic foam are very suitable for chilled water applications. Minimum thickness recommended for cellular glass insulation is 40 mm (1.5 inches). The reason is that the breakage rate during shipment of 25 mm (one inch) thick cellular insulation is too high to be economical. For faced rigid cellular phenolic foam, recommended minimum thickness is 25 mm (one inch).

For cryogenic equipment handling media between minus 34 and minus 18 degrees C (30 and minus one degree F), use cellular glass or faced rigid cellular phenolic foam insulation.

Economic insulation thickness recommendations (EITR) are based on three factors: energy, economics, and environment. Design conditions are as follows:

1. Ambient Temperature: 27 degrees C (80 degrees F), Still Air.

2. Jacket Surface Emissivity: 0.2 Metal, 0.9 All Purpose.

3. Surface Temperatures: 29 degrees C (85 degrees F) nominal for service temperatures under 176 degrees C (350 degrees F); maximum 60 degrees C (140 degrees F) for high service temperatures at and above 177 degrees C (351 degrees F).

4. Average energy cost of six dollars per 1,055,000 kJ (million Btu's).

EITR is a term used by North America Insulation Manufacturers Association (NAIMA), Commercial/Industrial Insulation Committee. Current member companies are: Knauf Fiber Glass, CertainTeed, Manville, Partek North America, Rock Wool Manufacturing, and Owen Corning Fiberglass. Data of mineral fiber and calcium silicate are supplied by NAIMA. Data of cellular glass are supplied by Pittsburgh Corning Corporation. Other data are obtained from manufacturers' published documents. Insulation thickness calculation was generated by manufacturers. Individual and precise calculation may be done by using computer programs such as NAIMA 3 E's Insulation Thickness Computer

Program. These computer programs shall comply with ASTM C 680, 1989 "Determination of Heat Gain or Loss and the Surface Temperatures of Insulated Pipe and Equipment Systems by the Use of a Computer Program".

For LANTNAVFACENGCOM projects, when there are two rows of insulation thickness for calcium silicate and mineral fiber, delete first-row data and use only second-row data identified with an asterisk. For other EFDs, delete second-row data. Delete data from High Temperature Water and Brine Systems.

For SOUTHNAVFACENGCOM projects, select first option of "Chilled Water (Supply & Return) & Dual Temperature Piping, 4 degrees C (39 degrees F) nominal" Service.

For PACNAVFACENGCOM projects in high humidity (tropical) areas, delete use of mineral fiber on chilled water, refrigerant section, and other cold piping.

****

TABLE 2
Piping Insulation Thickness (mm and °C)

For flexible cellular foam the thickness should be 13mm instead of 15mm. Economic thickness or prevention of condensation is the basis of these tables. If prevention of condensation is the criterium, the ambient temperature and relative humidity must be stated.

		Tube And Pipe Size (mm)				
Service	Material	<25	25-<40	40-<100	100-<200	>or = 200
[Chilled Water (Supply & Return, & Dual Temperature Piping) (4.44°C Nominal)]	Cellular Glass	40	50	50	65	80
	Faced Phenol Foam	25	25	25	40	50
	Polyisocianurate	25	25	25	25	25
[Chilled Water (Supply & Return, & Dual Temperature Piping) (4.44°C Nominal)]	Cellular Glass	40	40	40	40	50
	Flex Elas Cell'r	25	25	25	N/A	N/A
	Faced Phenol Foam	25	25	25	25	40
Heating Hot Water Supply & Return, Heated Oil (Max. 121°C)	Mineral Fiber	40	40	50	50	50
	Calcium Silicate	65	65	80	80	80
	Cellular Glass	50	65	75	80	80
	Perlite	65	65	80	80	80
	Polyisocianurate	25	25	40	40	40
Cold Domestic Water Piping, Makeup Water, & Drinking Fountain	Cellular Glass	40	40	40	40	40
	Flex Elas Cell'r	25	25	25	N/A	N/A
	Faced Phenol Foam	25	25	25	25	25
	Polyisocianurate	25	25	25	25	25

TABLE 2
Piping Insulation Thickness (mm and °C)

For flexible cellular foam the thickness should be 13mm instead of 15mm. Economic thickness or prevention of condensation is the basis of these tables. If prevention of condensation is the criterium, the ambient temperature and relative humidity must be stated.

		Tube And Pipe Size (mm)				
Service	Material	<25	25-<40	40-<100	100-<200	>or = 200
Drain Piping						
Hot Domestic Water Supply and Recirculating Piping (Max. 93°C)	Mineral Fiber	25	25	25	40	40
	Cellular Glass	40	40	40	50	50
	Flex Elas Cell'r	25	25	25	N/A	N/A
	Polyisocianurate	25	25	25	25	40
Refrigerant Suction Piping (1.67°C nominal)	Flex Elas Cell'r	25	25	25	N/A	N/A
	Cellular Glass	40	40	40	40	40
	Faced Phenol Foam	25	25	25	25	25
	Polyisocianurate	25	25	25	25	25
Compressed Air Discharge, Steam, and Condensate Return (94 to 121°C)	Mineral Fiber	40 40*	40 50*	50 65*	50 80*	50 90*
	Calcium Silicate	65	80	100	100	115
	Cellular Glass	50	65	80	80	80
	Perlite	65	80	100	100	115
	Polyisocianurate	40	40	50	50	50
Exposed Lavatory Drains, Exposed Domestic Water Piping & Drains to Areas for Handicap Personnel	Flex Elas Cell'r	13	13	13	13	15
Horizontal Roof Drain Leaders (including Underside of Roof Drain Fitting)	Cellular Glass	40	40	40	40	40
	Flex Elas Cell'r	25	25	25	N/A	N/A
	Faced Phenol Foam	25	25	25	25	25
	Polyisocianurate	25	25	25	25	25
A/C condensate Drain Located Inside Bldg.	Cellular Glass	40	40	40	40	40
	Flex Elas Cell'r	25	25	25	N/A	N/A
	Faced Phenol Foam	25	25	25	25	25
Medium Temp-erature Hot Water and Steam (122 to 176°C)	Mineral Fiber	40 65*	80 80*	80 90*	100	100
	Calcium Silicate	65	90	115	115	125
	Perlite	65	90	115	115	125
High Temperature Water (177 to 204°C) and Steam (177 to 260°C)	Mineral Fiber	65	80	80	100	100
	Calcium Silicate	100	115	150	150	150
	Perlite	100	115	150	150	150
	Polyisocianurate	25	25	25	25	25

TABLE 2

Piping Insulation Thickness (mm and °C)

For flexible cellular foam the thickness should be 13mm instead of 15mm. Economic thickness or prevention of condensation is the basis of these tables. If prevention of condensation is the criterium, the ambient temperature and relative humidity must be stated.

		Tube And Pipe Size (mm)				
Service	Material	<25	25-<40	40-<100	100-<200	>or = 200
Brine Systems Cryogenics (Minus 34 to Minus 18°C)	Cellular Glass	65	65	80	80	90
	Flex Elas Cell'r	25	25	N/A	N/A	N/A
	Faced Phenol Foam	40	40	50	50	50
	Polyisocianurate	40	40	50	50	50
Brine Systems, Cryogenics (Minus 18 to 1.11°C)	Cellular Glass	50	50	50	65	80
	Flex Elas Cell'r	25	25	25	N/A	N/A
	Faced Phenol Foam	25	25	25	40	40
	Polyisocianurate	25	25	25	40	40

****

NOTE: For LANTNAVFACENGCOM projects, when there are two rows of insulation thickness for calcium silicate and mineral fiber, delete first-row data and use only second-row data identified with an asterisk. For other EFDs, delete second-row data. Delete data from High Temperature Water and Brine Systems.

For SOUTHNAVFACENGCOM projects, select first option of "Chilled Water (Supply & Return) & Dual Temperature Piping, 4.50 degrees C (40 degrees F) nominal" Service.

For PACNAVFACENGCOM projects in high humidity (tropical) areas, do not add mineral fiber on chilled water, refrigerant section, and other cold piping to Table 1.

****

TABLE 2

Piping Insulation Thickness (inch and °F)

		Tube And Pipe Size (Inches)				
Service	Material	<1	1- <1.5	1.5- <4	4- <8	>or = to 8
[Chilled Water (Supply & Return, & Dual Temperature Piping) (40°F Nominal)]	Cellular Glass	1.5	2	2	2.5	3
	Faced Phenol Foam	1	1	1	1.5	1.5
	Polyisocianurate	1	1	1	1	1

TABLE 2
Piping Insulation Thickness (inch and °F)

Service	Material	Tube And Pipe Size (Inches) <1	1- <1.5	1.5- <4	4- <8	>or = to 8
[Chilled Water (Supply & Return, & Dual Temperature Piping) (40°F Nominal)]	Cellular Glass	1.5	1.5	1.5	1.5	2
	Flex Elas Cell'r	1	1	1	N/A	N/A
	Faced Phenol Foam	1	1	1	1	1.5
Heating Hot Water Supply & Return, Heated Oil (Max. 250°F)	Mineral Fiber	1.5	1.5	2	2	2
	Calcium Silicate	2.5	2.5	3	3	3
	Cellular Glass	2	2 5	3	3	3
	Perlite	2.5	2.5	3	3	3
	Polyisocianurate	1	1	1.5	1.5	1.5
Cold Domestic Water Piping, Makeup Water, & Drinking Fountain Drain Piping	Cellular Glass	1.5	1.5	1.5	1.5	1.5
	Flex Elas Cell'r	1	1	1	N/A	N/A
	Faced Phenol Foam	1	1	1	1	1
	Polyisocianurate	1	1	1	1	1
Hot Domestic Water Supply and Recirculating Piping (Max 200°F)	Mineral Fiber	1	1	1	1.5	1.5
	Cellular Glass	1.5	1.5	1.5	2	2
	Flex Elas Cell'r	1	1	1	N/A	N/A
	Polyisocianurate	1	1	1	1	1.5
Refrigerant Suction Piping (35°F nominal)	Flex Elas Cell'r	0.5	0.5	1	N/A	N/A
	Cellular Glass	1.5	1.5	1.5	1.5	1.5
	Faced Phenol Foam	1	1	1	1	1
	Polyisocianurate	1	1	1	1	1
Compressed Air Discharge, Steam, and Condensate Return (201°F to 250°F)	Mineral Fiber	1.5 1.5*	1.5 2*	2 2.5*	2 3*	2 3.5*
	Calcium Silicate	2.5	3	4	4	4.5
	Cellular Glass	2	2.5	3	3	3
	Perlite	2.5	3	4	4	4.5
	Polyisocianurate	1.5	1.5	2	2	2
Exposed Lavatory Drains, Exposed Domestic Water Piping & Drains to Areas for Handicap Personnel	Flex Elas Cell'r	0.5	0.5	0.5	0.5	0.5
Horizontal Roof Drain Leaders (including Underside of Roof Drain Fitting)	Cellular Glass	1.5	1.5	1.5	1.5	1.5
	Flex Elas Cell'r	1	1	1	1	1
	Faced Phenol Foam	1	1	1	1	1
	Polyisocianurate	1	1	1	1	1
A/C condensate Drain Located	Cellular Glass	1.5	1.5	1.5	1.5	1.5
	Flex Elas Cell'r	1	1	1	N/A	N/A

TABLE 2
Piping Insulation Thickness (inch and °F)

Service	Material	Tube And Pipe Size (Inches) <1	1- <1.5	1.5- <4	4- <8	>or = to 8
Inside Bldg.	Faced Phenol Foam	1	1	1	1	1
Medium Temp- erature Hot Water and Steam (251°F to 350°F)	Mineral Fiber	1.5 2.5*	3	3 3.5*	4	4
	Calcium Silicate	2.5	3.5	4.5	4.5	5
	Perlite	2.5	3.5	4.5	4.5	5
High Temperature Water (351o to 400°F) and Steam (351°F to 500°F)	Mineral Fiber	2.5	3	3	4	4
	Calcium Silicate	4	4.5	6	6	6
	Perlite	4	4.5	6	6	6
	Polyisocianurate	1	1	1	1	1
Brine Systems Cryogenics (Minus 30 to Zero°F)	Cellular Glass	2.5	2.5	3	3	3.5
	Flex Elas Cell'r	1	1	N/A	N/A	N/A
	Faced Phenol Foam	1.5	1.5	2	2	2
	Polyisocianurate	1.5	1.5	2	2	2
Brine Systems, Cryogenics (Zero to 34°F)	Cellular Glass	2	2	2	2.5	3
	Flex Elas Cell'r	1	1	1	N/A	N/A
	Faced Phenol Foam	1	1	1	1.5	1.5
	Polyisocianurate	1	1	1	1.5	1.5

3.2.2 Aboveground Cold Pipelines

****

NOTE: Insulation may be omitted on domestic cold-water piping and interior roof drains where condensation and freezing are not problems. However, the designer must maintain conditioned space control under cooling conditions - meet the energy budget, not allow condensation formation and not allow freezing.

****

The following cold pipelines for minus 34 to plus 16 degrees C minus 30 to plus 60 degrees F, shall be insulated per Table 2 except those piping listed in subparagraph Pipe Insulation in PART 3 as to be omitted. This includes but is not limited to the following:

a. [Domestic cold and chilled drinking water.]

b. Make-up water.

c. Horizontal and vertical portions of interior roof drains.

d. Refrigerant suction lines.

e. Chilled water.

f. Dual temperature water, i.e. HVAC hot/chilled water.

g. Air conditioner condensate drains.

h. Brine system cryogenics

i. Exposed lavatory drains and domestic water lines serving plumbing fixtures for handicap persons.

3.2.2.1 Insulation Material and Thickness

****

NOTE: Table 1 is not all inclusive of service insulation requirements. Edit, modify, and add to the tables as required for your project. Consideration may be given to increasing or decreasing the thickness of insulation required if, in the judgement of the designer, the situation warrants. For example, hot water piping in conditioned spaces may not require the tabulated thickness; or extremely cold systems in a high humidity climate may require additional insulation.

The designer should take into consideration the dew point temperature of the area in which the system is to be built. This is separate from the design dry bulb and design wet bulb temperatures, and should not be confused with the information provided in TM 5-785. When accounting for the dew point for design of the insulation thickness, consider using a relative humidity range of 80 to 90 percent unless you are in unusual circumstances. In very dry environments (Denver) consider using a relative humidity less than 80 percent, and remember to meet the requirements of the energy budget. In lower humidity environments, use the lower end of this range outdoors (80 to 85%). In high humidity environments use 90 percent. Indoors, where the humidity is to be controlled at 50 percent, it is more appropriate to design to 70 percent.

ASHRAE 90.1 insulation standards is a reference the designer should use to introduce a different material, or utilize an existing material type for an application that is not listed, or is outside the temperature range listed in Table 2. Table 2 may be modified for regions that meet one of the following conditions from TM 5-810-1. A wet bulb temperature of 19.4 degrees C (67 degrees F) or higher and the outside design relative humidity is 50 percent or higher (dew point temperature greater than 16 C (60 F)) for 3,000 hours or more. A wet bulb temperature of 22.8 degrees C (73 degrees F) or higher and the outside design relative humidity is 50 percent or higher (dew point temperature greater than 19 C (67 F)) for 1,500 hours or more. (Outside design relative humidity based on the 2.5 percent dry bulb and 5.0 percent wet bulb temperatures.) (Weather data obtained from TM 5-785.)

Further references for recommended thickness includes the Standard Mechanical Code and manufacturers recommended thickness tables. The refrigerant suction piping thickness was determined for 35 degrees F service and the chilled water supply and return and dual temperature piping thickness was determined for 40 degrees F nominal service temperature.

****

Insulation thickness for cold pipelines shall be determined using Table 2.

3.2.2.2 Jacket for Mineral Fiber, Cellular Glass, Phenolic Foam, and Polyisocyanurate Foam Insulated Pipe

****

NOTE: In high abuse areas such as janitor closets and traffic areas in equipment rooms and kitchens, aluminum jackets will be shown. Normally, pipe insulation to the 1.8 m (6 foot) level will be protected in high abuse areas. The designer will specifically indicate what pipes are to be provided with aluminum jackets.

****

Insulation shall be covered with a factory applied vapor retarder jacket or field applied seal welded PVC jacket. Insulation inside the building, to be protected with an aluminum jacket, shall have the insulation and vapor retarder jacket installed as specified herein. The aluminum jacket shall be installed as specified for piping exposed to weather, except sealing of the laps of the aluminum jacket is not required. In high abuse areas such as janitor closets and traffic areas in equipment rooms, kitchens, and mechanical rooms, aluminum jackets shall be providedfor pipe insulation to the 1.8 m 6 ft level. Other areas that specifically require protection to the 1.8 m 6 ft level are [_____].

3.2.2.3 Installing Insulation for Straight Runs Hot and Cold Pipe

a. Insulation shall be applied to the pipe with joints tightly butted. All butted joints and ends shall be sealed with joint sealant and sealed with a vapor retarder coating or PVDC adhesive tape.

b. Longitudinal laps of the jacket material shall overlap not less than 38 mm 1-1/2 inches. Butt strips 75 mm 3 inches wide shall be provided for circumferential joints.

c. Laps and butt strips shall be secured with adhesive and stapled on 100 mm 4 inch centers if not factory self-sealing. If staples are used, they shall be sealed per item "e." below. Note that staples are not required with cellular glass systems.

d. Factory self-sealing lap systems may be used when the ambient temperature is between 4 and 50 degrees C 40 and 120 degrees F during installation. The lap system shall be installed in accordance with manufacturer's recommendations. Stapler shall be used only if specifically recommended by the manufacturer. Where gaps occur, the section shall be replaced or the gap repaired by

applying adhesive under the lap and then stapling.

e. All Staples, including those used to repair factory self-seal lap systems, shall be coated with a vapor retarder coating or PVDC adhesive tape. All seams, except those on factory self-seal systems shall be coated with vapor retarder coating or PVDC adhesive tape.

f. Breaks and punctures in the jacket material shall be patched by wrapping a strip of jacket material around the pipe and securing it with adhesive, stapling, and coating with vapor retarder coating or PVDC adhesive tape. The patch shall extend not less than 38 mm 1-1/2 inches past the break.

g. At penetrations such as thermometers, the voids in the insulation shall be filled and sealed with vapor retarder coating or PVDC adhesive tape.

h. Installation of flexible elastomeric cellular pipe insulation shall be by slitting the tubular sections and applying them onto the piping or tubing. Alternately, whenever possible slide un-slit sections over the open ends of piping or tubing. All seams and butt joints shall be secured and sealed with adhesive. When using self seal products only the butt joints shall be secured with adhesive. Insulation shall be pushed on the pipe, never pulled. Stretching of insulation may result in open seams and joints. All edges shall be clean cut. Rough or jagged edges of the insulation shall not be permitted. Proper tools such as sharp knives shall be used. Grade 1, Type II sheet insulation when used on pipe larger than 150 mm 6 inches shall not be stretched around the pipe. On pipes larger than 300 mm 12 inches, adhere sheet insulation directly to the pipe on the lower 1/3 of the pipe.

3.2.2.4 Insulation for Fittings and Accessories

a. Pipe insulation shall be tightly butted to the insulation of the fittings and accessories. The butted joints and ends shall be sealed with joint sealant and sealed with a vapor retarder coating or PVDC adhesive tape.

b. Precut or preformed insulation shall be placed around all fittings and accessories and shall conform to MICA plates except as modified herein: 5 for anchors; 10, 11, and 13 for fittings; 14 for valves; and 17 for flanges and unions. Insulation shall be the same insulation as the pipe insulation, including same density, thickness, and thermal conductivity. Where precut/preformed is unavailable, rigid preformed pipe insulation sections may be segmented into the shape required. Insulation of the same thickness and conductivity as the adjoining pipe insulation shall be used. If nesting size insulation is used, the insulation shall be overlapped 50 mm 2 inches or one pipe diameter. Elbows insulated using segments shall conform to MICA Tables 12.20 "Mitered Insulation Elbow'.

c. Upon completion of insulation installation on flanges, unions, valves, anchors, fittings and accessories, terminations, seams, joints and insulation not protected by factory vapor retarder jackets or PVC fitting covers shall be protected with PVDC

adhesive tape or two coats of vapor retarder coating with a minimum total thickness of 2.0 mm 1/16 inch, applied with glass tape embedded between coats. Tape seams shall overlap 25 mm 1 inch. The coating shall extend out onto the adjoining pipe insulation 50 mm 2 inches. Fabricated insulation with a factory vapor retarder jacket shall be protected with PVDC adhesive tape or two coats of vapor retarder coating with a minimum thickness of 2 mm 1/16 inch and with a 50 mm 2 inch wide glass tape embedded between coats. Where fitting insulation butts to pipe insulation, the joints shall be sealed with a vapor retarder coating and a 100 mm 4 inch wide ASJ tape which matches the jacket of the pipe insulation.

d. Anchors attached directly to the pipe shall be insulated for a sufficient distance to prevent condensation but not less than 150 mm 6 inches from the insulation surface.

e. Insulation shall be marked showing the location of unions, strainers, and check valves.

3.2.2.5 Optional PVC Fitting Covers

At the option of the Contractor, premolded, one or two piece PVC fitting covers may be used in lieu of the vapor retarder and embedded glass tape. Factory precut or premolded insulation segments shall be used under the fitting covers for elbows. Insulation segments shall be the same insulation as the pipe insulation including same density, thickness, and thermal conductivity. The covers shall be secured by PVC vapor retarder tape, adhesive, seal welding or with tacks made for securing PVC covers. Seams in the cover, and tacks and laps to adjoining pipe insulation jacket, shall be sealed with vapor retarder tape to ensure that the assembly has a continuous vapor seal.

3.2.3 Aboveground Hot Pipelines

All hot pipe lines above 16 degrees C 60 degrees F, except those piping listed in subparagraph Pipe Insulation in PART 3 as to be omitted, shall be insulated per Table 2. This includes but is not limited to the following:

a. Domestic hot water supply & re-circulating system.

b. Steam.

c. Condensate & compressed air discharge.

d. Hot water heating.

e. Heated oil.

f. Water defrost lines in refrigerated rooms.

Insulation shall be covered, in accordance with manufacturer's recommendations, with a factory applied Type II jacket or field applied aluminum where required or seal welded PVC.

3.2.4 Piping Exposed to Weather

Piping exposed to weather shall be insulated and jacketed as specified for the applicable service inside the building. After this procedure, an

aluminum jacket or PVC jacket shall be applied. PVC jacketing requires no factory-applied jacket beneath it, however an all service jacket shall be applied if factory applied jacketing is not furnished. Flexible elastomeric cellular insulation exposed to weather shall be treated in accordance with paragraph INSTALLATION OF FLEXIBLE ELASTOMERIC CELLULAR INSULATION in PART 3.

3.2.4.1 Aluminum Jacket

The jacket for hot piping may be factory applied. The jacket shall overlap not less than 50 mm 2 inches at longitudinal and circumferential joints and shall be secured with bands at not more than 300 mm 12 inch centers. Longitudinal joints shall be overlapped down to shed water and located at 4 or 8 o'clock positions. Joints on piping 16 degrees C 60 degrees F and below shall be sealed with caulking while overlapping to prevent moisture penetration. Where jacketing on piping 16 degrees C 60 degrees F and below abuts an un-insulated surface, joints shall be caulked to prevent moisture penetration. Joints on piping above 16 degrees C 60 degrees F shall be sealed with a moisture retarder.

3.2.4.2 Insulation for Fittings

Flanges, unions, valves, fittings, and accessories shall be insulated and finished as specified for the applicable service. Two coats of breather emulsion type weatherproof mastic (impermeable to water, permeable to air) recommended by the insulation manufacturer shall be applied with glass tape embedded between coats. Tape overlaps shall be not less than 25 mm 1 inch and the adjoining aluminum jacket not less than 50 mm 2 inches. Factory preformed aluminum jackets may be used in lieu of the above. Molded PVC fitting covers shall be provided when PVC jackets are used for straight runs of pipe. PVC fitting covers shall have adhesive welded joints and shall be weatherproof.

3.2.4.3 PVC Jacket

PVC jacket shall be ultraviolet resistant and adhesive welded weather tight with manufacturer's recommended adhesive. Installation shall include provision for thermal expansion.

3.2.5 Below Ground Pipe Insulation

****

NOTE: Where significant amounts (approximately 8 meters (25 feet)) of below grade piping is to be insulated, a separate specification section will be developed to allow factory pre-insulated systems as an alternate to field applied systems. Portions of the underground piping that are to be insulated using this paragraph will be indicated on the drawings.

****

Below ground pipes shall be insulated in accordance with Table 2, except as precluded in subparagraph Pipe Insulation in PART 3. This includes, but is not limited to the following:

a. Heated oil.

b. Domestic hot water.

c. Heating hot water.

d. Dual temperature water.

e. Steam.

f. Condensate.

3.2.5.1 Type of Insulation

Below ground pipe shall be insulated with Cellular Glass insulation, or with Polyisocyanurate insulation, in accordance with manufacturer's instructions for application with thickness as determined from Table 2 (whichever is the most restrictive).

3.2.5.2 Installation of Below ground Pipe Insulation

a. Bore surfaces of the insulation shall be coated with a thin coat of gypsum cement of a type recommended by the insulation manufacturer. Coating thickness shall be sufficient to fill surface cells of insulation. Mastic type materials shall not be used for this coating. Note that unless this is for a cyclic application (i.e., one that fluctuates between high and low temperature on a daily process basis) there is no need to bore coat the material.

b. Stainless steel bands, 19 mm 3/4 inch wide by 0.508 mm 0.020 inch thick shall be used to secure insulation in place. A minimum of two bands per section of insulation shall be applied. As an alternate, fiberglass reinforced tape may be used to secure insulation on piping up to 300 mm 12 inches in diameter. A minimum of two bands per section of insulation shall be applied.

c. Insulation shall terminate at anchor blocks but shall be continuous through sleeves and manholes.

d. At point of entry to buildings, underground insulation shall be terminated 50 mm 2 inches inside the wall or floor, shall butt tightly against the aboveground insulation and the butt joint shall be sealed with high temperature silicone sealant and covered with fibirous glass tape.

e. Provision for expansion and contraction of the insulation system shall be made in accordance with the insulation manufacturer's recommendations.

f. Flanges, couplings, valves, and fittings shall be insulated with factory pre-molded, prefabricated, or field-fabricated sections of insulation of the same material and thickness as the adjoining pipe insulation. Insulation sections shall be secured as recommended by the manufacturer.

g. Insulation, including fittings, shall be finished with three coats of asphaltic mastic, with 6 by 5.5 mesh synthetic reinforcing fabric embedded between coats. Fabric shall be overlapped a minimum of 50 mm 2 inches at joints. Total film thickness shall be a minimum of 4.7 mm 3/16 inch. As an alternate, a prefabricated bituminous laminated jacket, reinforced with

internal reinforcement mesh, shall be applied to the insulation. Jacketing material and application procedures shall match manufacturer's written instructions.

h. At termination points, other than building entrances, the mastic and cloth or tape shall cover the ends of insulation and extend 50 mm 2 inches along the bare pipe.

3.3 DUCTWORK, PLENUMS, CASINGS, AND ACCESSORIES INSULATION INSTALLATION

****

NOTE: Insulation may be omitted on heating duct in heated spaces. Designer will determine if internally lined ducts are comparable in insulating value to those unlined ducts to be insulated. If not, field insulation will be added.

The designer must maintain conditioned space control under cooling and heating conditions - meet the energy budget, and not allow condensation formation. The following do not require insulation: factory fabricated double wall internally insulated duct, glass fiber duct, site-erected air conditioning casings and plenums constructed of factory-insulated sheet metal panels, ducts internally lined with insulation or sound absorbing material, unless indicated otherwise, return ducts in ceiling spaces or as indicated, supply ducts in ceiling spaces which are used as return air plenums (or as indicated), factory pre-insulated flexible ducts, ducts within HVAC equipment, exhaust air ducts unless noted, and duct portions inside walls or floor-ceiling space in which both sides of the space are exposed to conditioned air and the space is not vented or exposed to unconditioned air.

Ceiling spaces shall be defined as those spaces between the ceiling and bottom of floor deck or roof deck inside the air-conditioned space insulated envelope, and ceilings that form plenums.

****

Except for oven hood exhaust duct insulation, corner angles shall be installed on external corners of insulation on ductwork in exposed finished spaces before covering with jacket. [Duct insulation shall be omitted on exposed supply and return ducts in air conditioned spaces [where the difference between supply air temperature and room air temperature is less than 9 degrees C 15 degrees F] unless otherwise shown.] Air conditioned spaces shall be defined as those spaces directly supplied with cooled conditioned air (or provided with a cooling device such as a fan-coil unit) and heated conditioned air (or provided with a heating device such as a unit heater, radiator or convector).

3.3.1 Duct Insulation Thickness

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NOTE: The following tables are adapted from ASHRAE standard 90.1. They may be used to modify the thicknesses listed in Table 3. The thicknesses

listed are recommended, and may be changed at the discretion of the designer Limit thickness of flexible elastomeric cellular insulation to 25 mm (1 inch) due to flame spread and smoke development rating.

Table 3
Minimum Duct Insulation (mm and °C)

Duct Location	Cooling: Annual Cooling Degree Days Base 18 C	Cooling: Insulation R-Value (sm K)/W	Heating: Annual Heating Degree Days Base 18 C	Heating: Insulation R-Value (sm K)/W
Exterior Of Building	<260	0.58	<816	0.58
	260 - 621	0.88	816 - 2482	0.88
	622 - 1093	1.14	2483 - 4149	1.14
	>1093	1.41	<4149	1.41
	Temperature Difference	Insulation R-Value (sm K)/W	Temperature Difference	Insulation R-Value (sm K)/W
Inside building or None reqd in uncondi-tioned spaces	<-9.4	None reqd	<-9.4	
	-9.4<TD<4.4	0.58	-9.4<TD<4.4	0.58
	4.4<TD	0.88	4.4<TD	0.88

These R-values do not include the film resistances. The required minimum thicknesses do not consider water vapor transmission and condensation. Additional insulation, vapor retarders, or both, may be required to limit vapor transmission and condensation. Where ducts are designed to convey both heated and cooled air, duct insulation shall be as required by the most restrictive condition. Where exterior walls are used as plenum walls, wall insulation shall be a required by the most restrictive condition of this section or the insulation for the building envelope. Cooling ducts are those designed to convey mechanically cooled air or return ducts in such systems. Heating ducts are those designed to convey mechanically heated air or return ducts in such systems. Thermal resistance will be measured in accordance with ASTM C 518 at a mean temperature of 24 degrees C. The Temperature difference is at design conditions between the space within which the duct is located and the design air temperature in the duct. Resistance for runouts to terminal devices less than 3.048 m in length need not exceed 0.58 (sm K)/W. Unconditioned spaces include crawlspaces and attics.

Table 3
Minimum Duct Insulation (inches and °F)

Duct Location	Cooling: Annual Cooling Degree Days Base 65 F	Cooling: Insulation R-Value (h sf F)/Btu	Heating: Annual Heating Degree Days Base 65 F	Heating: Insulation R-Value (h sf F)/Btu
Exterior	<500 -	3.3	<1500	3.3

Table 3
Minimum Duct Insulation (inches and °F)

	Cooling		Heating	
Of Building	500 - 1150	5.0	1500 - 4500	5.0
	1151 - 2000	6.5	4501 - 7500	6.5
	>2000	8.0	>7500	8.0

	Temperature Difference	Insulation R-Value (h sf F)/Btu	Temperature Difference	Insulation R-Value (h sf F)/Btu
Inside building envelope or in un-conditioned spaces	<15	None reqd	<15	None reqd
	15<TD<40	3.3	15<TD<40	3.3
	40<TD	5.0	40<TD	5.0

These R-values do not include the film resistances. The required minimum thicknesses do not consider water vapor transmission and condensation. Additional insulation, vapor retarders, or both, may be required to limit vapor transmission and condensation. Where ducts are designed to convey both heated and cooled air, duct insulation shall be as required by the most restrictive condition. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of this section or the insulation for the building envelope. Cooling ducts are those designed to convey mechanically cooled air or return ducts in such systems. Heating ducts are those designed to convey mechanically heated air or return ducts in such systems. Thermal Resistance is to be measured in accordance with ASTM C 518 at a mean temperature of 75 degrees F. The temperature difference is at design conditions between the space within which the duct is located and the design air temperature in the duct. Resistance for run-outs to terminal devices less than 10 ft in length need not exceed 3.3 (h sf F)/Btu. Unconditioned spaces include crawlspaces and attics.

****

Duct insulation thickness shall be in accordance with Table 4.

Table 4 - Minimum Duct Insulation (mm)

Cold Air Ducts	50
Relief Ducts	40
Fresh Air Intake Ducts	40
Warm Air Ducts	50
Relief Ducts	40
Fresh Air Intake Ducts	40

Table 4 - Minimum Duct Insulation (inches)

Cold Air Ducts	2.0

Table 4 - Minimum Duct Insulation (inches)

Relief Ducts	1.5
Fresh Air Intake Ducts	1.5
Warm Air Ducts	2.0
Relief Ducts	1.5
Fresh Air Intake Ducts	1.5

3.3.2 Insulation and Vapor Retarder for Cold Air Duct

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NOTE: Cold air ducts needing insulation are ducts that handle air at or below 16 degrees C (60 degrees F). Mixing boxes, relief air ducts, and filter boxes should not be insulated unless condensation is a problem. Insulation may be omitted on that portion of return air ducts installed in the ceiling spaces where condensation is not a problem, and on that portion of supply ducts installed in ceiling spaces used as a return air plenum where condensation is not a problem. The designer is required to provide calculations to prove, if insulation is not provided for ducts or equipment, the space will be properly cooled and condensation will not form on ductwork or equipment. For ducts to be used for both heating and cooling, the requirements for cold ducts will govern.

****

Insulation and vapor retarder shall be provided for the following cold air ducts and associated equipment.

a. Supply ducts.

b. Return air ducts.

c. Relief ducts.

d. Flexible run-outs (field-insulated).

e. Plenums.

f. Duct-mounted coil casings.

g. Coil headers and return bends.

h. Coil casings.

i. Fresh air intake ducts.

j. Filter boxes.

k. Mixing boxes (field-insulated).

l. Supply fans (field-insulated).

m. Site-erected air conditioner casings.

n. Ducts exposed to weather.

o. Combustion air intake ducts.

Insulation for rectangular ducts shall be flexible type where concealed, minimum density 12 kg/cubic m 3/4 pcf, and rigid type where exposed, minimum density 48 kg/cubic m 3 pcf. Insulation for both concealed or exposed round/oval ducts shall be flexible type, minimum density 12 kg/cubic m 3/4 pcf or a semi rigid board, minimum density 48 kg/cubic m 3 pcf, formed or fabricated to a tight fit, edges beveled and joints tightly butted and staggered. Insulation for all exposed ducts shall be provided with either a white, paint-able, factory-applied Type I jacket or a field applied vapor retarder jacket coating finish as specified, the total field applied dry film thickness shall be approximately 2.0 mm 1/16 inch. Insulation on all concealed duct shall be provided with a factory-applied Type I or II vapor retarder jacket. Duct insulation shall be continuous through sleeves and prepared openings except firewall penetrations. Duct insulation terminating at fire dampers, shall be continuous over the damper collar and retaining angle of fire dampers, which are exposed to unconditioned air and which may be prone to condensate formation. Duct insulation and vapor retarder shall cover the collar, neck, and any un-insulated surfaces of diffusers, registers and grills. Vapor retarder materials shall be applied to form a complete unbroken vapor seal over the insulation. Sheet Metal Duct shall be sealed in accordance with Section 15895 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM.

3.3.2.1 Installation on Concealed Duct

a. For rectangular, oval or round ducts, flexible insulation shall be attached by applying adhesive around the entire perimeter of the duct in 150 mm 6 inch wide strips on 300 mm 12 inch centers.

b. For rectangular and oval ducts, 600 mm 24 inches and larger insulation shall be additionally secured to bottom of ducts by the use of mechanical fasteners. Fasteners shall be spaced on 400 mm 16 inch centers and not more than 400 mm 16 inches from duct corners.

c. For rectangular, oval and round ducts, mechanical fasteners shall be provided on sides of duct risers for all duct sizes. Fasteners shall be spaced on 400 mm 16 inch centers and not more than 400 mm 16 inches from duct corners.

d. Insulation shall be impaled on the mechanical fasteners (self stick pins) where used and shall be pressed thoroughly into the adhesive. Care shall be taken to ensure vapor retarder jacket joints overlap 50 mm 2 inches. The insulation shall not be compressed to a thickness less than that specified. Insulation shall be carried over standing seams and trapeze-type duct hangers.

e. Self-locking washers shall be installed where mechanical fasteners are used. The pin shall be trimmed back and bent over.

f. Jacket overlaps shall be secured with staples and tape as necessary to ensure a secure seal. Staples, tape and seams shall be coated with a brush coat of vapor retarder coating or PVDC adhesive tape.

g. Breaks in the jacket material shall be covered with patches of the same material as the vapor retarder jacket. The patches shall extend not less than 50 mm 2 inches beyond the break or penetration in all directions and shall be secured with tape and staples. Staples and tape joints shall be sealed with a brush coat of vapor retarder coating or PVDC adhesive tape.

h. At jacket penetrations such as hangers, thermometers, and damper operating rods, voids in the insulation shall be filled and the penetration sealed with a brush coat of vapor retarder coating or PVDC adhesive tape.

i. Insulation terminations and pin punctures shall be sealed and flashed with a reinforced vapor retarder coating finish or tape with a brush coat of vapor retarder coating.. The coating shall overlap the adjoining insulation and un-insulated surface 50 mm 2 inches. Pin puncture coatings shall extend 50 mm 2 inches from the puncture in all directions.

j. Where insulation standoff brackets occur, insulation shall be extended under the bracket and the jacket terminated at the bracket.

3.3.2.2 Installation on Exposed Duct Work

a. For rectangular ducts, rigid insulation shall be secured to the duct by mechanical fasteners on all four sides of the duct, spaced not more than 300 mm 12 inches apart and not more than 75 mm 3 inches from the edges of the insulation joints. A minimum of two rows of fasteners shall be provided for each side of duct 300 mm 12 inches and larger. One row shall be provided for each side of duct less than 300 mm 12 inches. Mechanical fasteners shall be as corrosion resistant as G60 coated galvanized steel, and shall indefinitely sustain a 22.7 kg 50 lb tensile dead load test perpendicular to the duct wall.

b. Duct insulation shall be formed with minimum jacket seams. Each piece of rigid insulation shall be fastened to the duct using mechanical fasteners. When the height of projections is less than the insulation thickness, insulation shall be brought up to standing seams, reinforcing, and other vertical projections and shall not be carried over. Vapor retarder jacket shall be continuous across seams, reinforcing, and projections. When height of projections is greater than the insulation thickness, insulation and jacket shall be carried over. Apply insulation with joints tightly butted. Neatly bevel insulation around name plates and access plates and doors.

c. Insulation shall be impaled on the fasteners; self-locking washers shall be installed and the pin trimmed or bent over.

d. Joints in the insulation jacket shall be sealed with a 100 mm 4 inch wide strip of tape. Tape seams shall be sealed with a brush coat of vapor retarder coating.

e. Breaks and ribs or standing seam penetrations in the jacket material shall be covered with a patch of the same material as the jacket. Patches shall extend not less than 50 mm 2 inches beyond the break or penetration and shall be secured with tape and

stapled. Staples and joints shall be sealed with a brush coat of vapor retarder coating.

f. At jacket penetrations such as hangers, thermometers, and damper operating rods, the voids in the insulation shall be filled and the penetrations sealed with a brush coat of vapor retarder coating.

g. Insulation terminations and pin punctures shall be sealed and flashed with a reinforced vapor retarder coating finish. The coating shall overlap the adjoining insulation and un-insulated surface 50 mm 2 inches. Pin puncture coatings shall extend 50 mm 2 inches from the puncture in all directions.

h. Oval and round ducts, flexible type, shall be insulated with factory Type I jacket insulation with minimum density of 12 kg per cubic meter 3/4 pcf, attached as per MICA standards.

3.3.3 Insulation for Warm Air Duct

****

NOTE: Warm air ducts needing insulation are ducts that handle air above 16 degrees C (60 degrees F). Mixing boxes, relief air ducts, and filter boxes should not be insulated unless condensation is a problem. Factory fabricated double-walled internally insulated duct exposed to the weather should be externally insulated on long runs of duct in cold climates. If insulation is required for unique building design, indicate on the drawings the locations the insulation is to be installed. Ducts for dual purposes will be as required for cold duct. Delete items below as required.

****

Insulation and vapor barrier shall be provided for the following warm air ducts and associated equipment:.

a. Supply ducts.

b. Return air ducts

c. Relief air ducts

d. Flexible run-outs (field insulated)

e. Plenums

f. Duct-mounted coil casings

g. Coil-headers and return bends

h. Coil casings.

i. Fresh air intake ducts

j. Filter boxes

k. Mixing boxes

l. Supply fans

m. Site-erected air conditioner casings

n. Ducts exposed to weather

Insulation for rectangular ducts shall be flexible type where concealed, and rigid type where exposed. Insulation on exposed ducts shall be provided with a white, paint-able, factory-applied Type II jacket, or finished with adhesive finish. Flexible type insulation shall be used for round ducts, with a factory-applied Type II jacket. Insulation on concealed duct shall be provided with a factory-applied Type II jacket. Adhesive finish where indicated to be used shall be accomplished by applying two coats of adhesive with a layer of glass cloth embedded between the coats. The total dry film thickness shall be approximately 2.0 mm 1/16 inch. Duct insulation shall be continuous through sleeves and prepared openings. Duct insulation shall terminate at fire dampers and flexible connections.

3.3.3.1 Installation on Concealed Duct

a. For rectangular, oval and round ducts, insulation shall be attached by applying adhesive around the entire perimeter of the duct in 150 mm 6 inch wide strips on 300 mm 12 inch centers.

b. For rectangular and oval ducts 600 mm 24 inches and larger, insulation shall be secured to the bottom of ducts by the use of mechanical fasteners. Fasteners shall be spaced on 450 mm 18 inch centers and not more than 450 mm 18 inches from duct corner.

c. For rectangular, oval and round ducts, mechanical fasteners shall be provided on sides of duct risers for all duct sizes. Fasteners shall be spaced on 450 mm 18 inch centers and not more than 450 mm 18 inches from duct corners.

d. The insulation shall be impaled on the mechanical fasteners where used. The insulation shall not be compressed to a thickness less than that specified. Insulation shall be carried over standing seams and trapeze-type hangers.

e. Self-locking washers shall be installed where mechanical fasteners are used and the pin trimmed and bent over.

f. Insulation jacket shall overlap not less than 50 mm 2 inches at joints and the lap shall be secured and stapled on 100 mm 4 inch centers.

3.3.3.2 Installation on Exposed Duct

a. For rectangular ducts, the rigid insulation shall be secured to the duct by the use of mechanical fasteners on all four sides of the duct, spaced not more than 400 mm 16 inches apart and not more than 150 mm 6 inches from the edges of the insulation joints. A minimum of two rows of fasteners shall be provided for each side of duct 300 mm 12 inches and larger and a minimum of one row for each side of duct less than 300 mm 12 inches.

b. Duct insulation with factory-applied jacket shall be formed with

minimum jacket seams, and each piece of rigid insulation shall be fastened to the duct using mechanical fasteners. When the height of projection is less than the insulation thickness, insulation shall be brought up to standing seams, reinforcing, and other vertical projections and shall not be carried over the projection. Jacket shall be continuous across seams, reinforcing, and projections. Where the height of projections is greater than the insulation thickness, insulation and jacket shall be carried over the projection.

c. Insulation shall be impaled on the fasteners; self-locking washers shall be installed and pin excess clipped and bent over.

d. Joints on jacketed insulation shall be sealed with a 100 mm 4 inch wide strip of tape and brushed with vapor retarder coating.

e. Breaks and penetrations in the jacket material shall be covered with a patch of the same material as the jacket. Patches shall extend not less than 50 mm 2 inches beyond the break or penetration and shall be secured with adhesive and stapled.

f. Insulation terminations and pin punctures shall be sealed with tape and brushed with vapor retarder coating.

g. Oval and round ducts, flexible type, shall be insulated with factory Type I jacket insulation, minimum density of 12 kg per cubic meter 3/4 pcf attached by staples spaced not more than 400 mm 16 inches and not more than 150 mm 6 inches from the degrees of joints. Joints shall be sealed in accordance with item "d." above.

3.3.4 Ducts Handling Air for Dual Purpose

For air handling ducts for dual purpose below and above 16 degrees C 60 degrees F, ducts shall be insulated as specified for cold air duct.

3.3.5 Insulation for Evaporative Cooling Duct

Evaporative cooling supply duct located in spaces not evaporatively cooled, shall be insulated. Material and installation requirements shall be as specified for duct insulation for warm air duct.

3.3.6 Duct Test Holes

After duct systems have been tested, adjusted, and balanced, breaks in the insulation and jacket shall be repaired in accordance with the applicable section of this specification for the type of duct insulation to be repaired.

3.3.7 Duct Exposed to Weather

3.3.7.1 Installation

Ducts exposed to weather shall be insulated and finished as specified for the applicable service for exposed duct inside the building. After the above is accomplished, the insulation shall then be further finished as detailed in the following subparagraphs.

3.3.7.2 Round Duct

Aluminum jacket with factory applied moisture retarder shall be applied with the joints lapped not less than 75 mm 3 inches and secured with bands located at circumferential laps and at not more than 300 mm 12 inch intervals throughout. Horizontal joints shall lap down to shed water and located at 4 or 8 o'clock position. Joints shall be sealed with caulking to prevent moisture penetration. Where jacketing abuts an un-insulated surface, joints shall be sealed with caulking.

3.3.7.3 Fittings

Fittings and other irregular shapes shall be finished as specified for rectangular ducts.

3.3.7.4 Rectangular Ducts

Two coats of weather barrier mastic reinforced with fabric or mesh for outdoor application shall be applied to the entire surface. Each coat of weatherproof mastic shall be 2.0 mm 1/16 inch minimum thickness. The exterior shall be a metal jacketing applied for mechanical abuse and weather protection, and secured with screws.

3.3.8 Kitchen Exhaust Duct Insulation

NFPA 96 for [ovens,] [griddles,] [deepfat fryers,] [steam kettles,] [vegetable steamers,] [high pressure cookers,] [and] [mobile serving units]. Provide insulation with 19 mm 3/4 inch wide, minimum 4 mm 0.15 inch thick galvanized steel bands spaced not over 305 mm 12 inches o.c.; or 16 gauge galvanized steel wire with corner clips under the wire; or with heavy welded pins spaced not over 305 mm 12 inches apart each way. Do not use adhesives.

3.4 EQUIPMENT INSULATION INSTALLATION

3.4.1 General

Removable insulation sections shall be provided to cover parts of equipment that must be opened periodically for maintenance including vessel covers, fasteners, flanges and accessories. Equipment insulation shall be omitted on the following:

a. Hand-holes.

b. Boiler manholes.

c. Cleanouts.

d. ASME stamps.

e. Manufacturer's nameplates.

3.4.2 Insulation for Cold Equipment

****

NOTE: Special cold equipment including Government-furnished equipment that requires field-applied insulation will be inserted in the appropriate paragraph.

****

Cold equipment below 16 degrees C 60 degrees F: Insulation shall be furnished on equipment handling media below 16 degrees C 60 degrees F including the following:

a. Pumps.

b. Refrigeration equipment parts that are not factory insulated.

c. Drip pans under chilled equipment.

d. Cold water storage tanks.

e. Water softeners.

f. Duct mounted coils.

g. Cold and chilled water pumps.

h. Pneumatic water tanks.

i. Roof drain bodies.

j. Air handling equipment parts that are not factory insulated.

k. Expansion and air separation tanks.

3.4.2.1 Insulation Type

****

NOTE: Additional data on insulation thickness may be found in manufacturers catalogs and computer sizing programs and from individual calculations. Care should be taken in the selection of an insulating material for high temperature equipment. If the equipment rises to high operating temperature in a short period of time, thermal stresses may occur in rigid insulations that may lead to cracking and subsequent deterioration of the insulation.

****

Insulation shall be suitable for the temperature encountered. Material and thicknesses shall be as shown in Table 5:

Legend

RMF: Rigid Mineral Fiber
FMF: Flexible Mineral Fiber
CS: Calcium Silicate
PL: Perlite
CG: Cellular Glass
FC: Flexible Elastomeric Cellular
PF: Phenolic Foam
PC: Polyisocyanurate Foam

TABLE 5
Insulation Thickness for Cold Equipment (mm and °C)

Equipment handling media at indicated temperature:	Material	Thickness
2 to 16 degrees C	CG	40 mm
	PF	40 mm
	FC	25 mm
	PC	25 mm
Minus 18 to 1 degree C	PF	40 mm
	PC	40 mm
	CG	75 mm
	FC	40 mm
Minus 34 to Minus 17 degrees C	PF	40 mm
	PC	40 mm
	CG	90 mm
	FC	45 mm

TABLE 5
Insulation Thickness for Cold Equipment (Inches and °F)

Equipment handling media at indicated temperature:	Material	Thickness
35 to 60 degrees F	CG	1.5 inches
	PF	1.5 inches
	FC	1.0 inches
	PC	1.0 inches
1 to 34 degrees F	PC	1.5 inches
	FC	1.5 inches
	CG	3.0 inches
	PF	1.5 inches
Minus 30 to 0 degrees F	PC	1.5 inches
	FC	1.75 inches
	CG	3.5 inches
	PF	1.5 inches

3.4.2.2 Pump Insulation

a. Insulate pumps by forming a box around the pump housing. The box shall be constructed by forming the bottom and sides using joints that do not leave raw ends of insulation exposed. Joints between sides and between sides and bottom shall be joined by adhesive with lap strips for rigid mineral fiber and contact adhesive for flexible elastomeric cellular insulation. The box shall conform to the requirements of MICA Insulation Stds plate No. 49 when using flexible elastomeric cellular insulation. Joints between top cover and sides shall fit tightly forming a female shiplap joint on the side pieces and a male joint on the top cover, thus making the top cover removable.

b. Exposed insulation corners shall be protected with corner angles.

c. Upon completion of installation of the insulation, including removable sections, two coats of vapor retarder coating shall be applied with a layer of glass cloth embedded between the coats. The total dry thickness of the finish shall be 2.0 mm 1/16 inch. A parting line shall be provided between the box and the removable sections allowing the removable sections to be removed without disturbing the insulation coating. Caulking shall be applied to parting line, between equipment and removable section insulation, and at all penetrations.

3.4.2.3 Other Equipment

a. Insulation shall be formed or fabricated to fit the equipment. To ensure a tight fit on round equipment, edges shall be beveled and joints shall be tightly butted and staggered.

b. Insulation shall be secured in place with bands or wires at intervals as recommended by the manufacturer but not more than 300 mm 12 inch centers except flexible elastomeric cellular which shall be adhered with contact adhesive. Insulation corners shall be protected under wires and bands with suitable corner angles.

c. Phenolic foam insulation shall be set in a coating of bedding compound and joints shall be sealed with bedding compound as recommended by the manufacturer. Cellular glass shall be installed in accordance with manufacturer's instructions. Joints and ends shall be sealed with joint sealant, and sealed with a vapor retarder coating.

d. Insulation on heads of heat exchangers shall be removable. Removable section joints shall be fabricated using a male-female shiplap type joint. The entire surface of the removable section shall be finished by applying two coats of vapor retarder coating with a layer of glass cloth embedded between the coats. The total dry thickness of the finish shall be 2.0 mm 1/16 inch.

e. Exposed insulation corners shall be protected with corner angles.

f. Insulation on equipment with ribs shall be applied over 150 x 150 mm 6 x 6 inches by 12 gauge welded wire fabric which has been cinched in place, or if approved by the Contracting Officer, spot welded to the equipment over the ribs. Insulation shall be secured to the fabric with J-hooks and 50 x 50 mm 2 x 2 inches washers or shall be securely banded or wired in place on 300 mm 12 inch centers.

3.4.2.4 Vapor Retarder

Upon completion of installation of insulation, penetrations shall be caulked. Two coats of vapor retarder coating shall be applied over insulation, including removable sections, with a layer of open mesh synthetic fabric embedded between the coats. The total dry thickness of the finish shall be 2.0 mm 1/16 inch. Caulking shall be applied to parting line between equipment and removable section insulation.

3.4.3 Insulation for Hot Equipment

****
NOTE: Special hot equipment such as sterilizers, expansion tanks for high temperature water systems, process equipment, and special Government-furnished equipment that requires field-applied insulation will be inserted in the appropriate subparagraphs. Expansion tanks on hot water heating systems will not normally be insulated.
****

Insulation shall be furnished on equipment handling media above 16 degrees C 60 degrees F including the following:

a. Converters.

b. Heat exchangers.

c. Hot water generators.

d. Water heaters.

e. Pumps handling media above 54 degrees C 130 degrees F.

f. Fuel oil heaters.

g. Hot water storage tanks.

h. Air separation tanks.

i. Surge tanks.

j. Flash tanks.

k. Feed-water heaters.

l. Unjacketed boilers or parts of boilers.

m. Boiler flue gas connection from boiler to stack (if inside).

n. Induced draft fans.

o. Fly ash and soot collectors.

p. Condensate receivers.

3.4.3.1 Insulation

****
NOTE: Additional data on insulation thickness may be found in manufacturers catalogs and computer sizing programs and from individual calculations. Care should be taken in the selection of an insulating material for high temperature equipment. If the equipment rises to high operating temperature in a short period of time, thermal stresses may occur in rigid insulations that may lead to cracking and subsequent deterioration of the insulation.

****

Insulation shall be suitable for the temperature encountered. Shell and tube-type heat exchangers shall be insulated for the temperature of the shell medium.

Insulation thickness for hot equipment shall be determined using Table 6:

Legend

RMF: Rigid Mineral Fiber
FMF: Flexible Mineral Fiber
CS: Calcium Silicate
PL: Perlite
CG: Cellular Glass
FC: Flexible Elastomeric Cellular
PF: Phenolic Foam
PC: Polyisocyanurate Foam

TABLE 6
Insulation Thickness for Hot Equipment (mm and °C)

Equipment handling steam or other media to indicated pressure or temperature limit	Material	Thickness
103.4 kPa	RMF	50 mm
or	FMF	50 mm
121 C	CS/PL	100 mm
	CG	75 mm
	PF	40 mm
	FC(<93 C)	25 mm
	PC	25 mm
1379.0kPa	RMF	75 mm
or	FMF	75 mm
204 C	CS/PL	100 mm
	CG	100 mm
316 C	RMF	125 mm
	FMF	150 mm
	CS/PL	150 mm
	CG	150 mm

316 C: Thickness necessary to limit the external temperature of the insulation to 50 C. Heat transfer calculations shall be submitted to substantiate insulation and thickness selection.

TABLE 6
Insulation Thickness for Hot Equipment (Inches and °F)

Equipment handling steam or media to indicated pressure or temperature limit:	Material	Thickness

15 psig or 250F	RMF FMF CS/PL CG PF FC (<200F) PC	2.0 inches 2.0 inches 4.0 inches 3.0 inches 1.5 inches 1.0 inches 1.0 inches
200 psig or 400 F	RMF FMF CS/PL CG	3.0 inches 3.0 inches 4.0 inches 4.0 inches
600 F	RMF FMF CS/PL CG	5.0 inches 6.0 inches 6.0 inches 6.0 inches

>600 F: Thickness necessary to limit the external temperature of the insulation to 120F. Heat transfer calculations shall be submitted to substantiate insulation and thickness selection.

3.4.3.2 Insulation of Boiler Stack and Diesel Engine Exhaust Pipe

Inside [boiler House] [mechanical Room], bevel insulation neatly around openings and provide sheet metal insulation stop strips around such openings. Apply a skim coat of hydraulic setting cement directly to insulation. Apply a flooding coat of adhesive over hydraulic setting cement, and while still wet, press a layer of glass cloth or tape into adhesive and seal laps and edges with adhesive. Coat glass cloth with adhesive. When dry, apply a finish coat of adhesive at can-consistency so that when dry no glass weave shall be observed. Provide metal jackets for [stacks] [and] [exhaust pipes] that are located above finished floor and spaces outside [boiler house] [mechanical room]. Apply metal jackets directly over insulation and secure with 19 mm 3/4 inch wide metal bands spaced on 457 mm 18 inch centers. Do not insulate name plates. Insulation type and thickness shall be in accordance with the following Table 7.

TABLE 7
Insulation and Thickness (mm and °C) for
Boiler Stack and Diesel Engine Exhaust Pipe

Service & Surface Temperature Range (Degrees C)	Material	Outside Diameter (mm) 6-32	40-80	90-125	150-250	280-900
Boiler Stack (Up to 204°C)	Mineral Fiber ASTM C 553 Class B-3, ASTM C 547 Class 1, or ASTM C 612 Class 1	NA	NA	80	90	100
	Calcium Silicate	NA	NA	80	90	100

TABLE 7
Insulation and Thickness (mm and °C) for
Boiler Stack and Diesel Engine Exhaust Pipe

Service & Surface Temperature Range (Degrees C)	Material	Outside Diameter (mm) 6-32	40-80	90-125	150-250	280-900
	ASTM C 533, Type 1					
	Cellular Glass ASTM C 552, Type II	40	40	40	50	65
Boiler Stack (205 to 315°C)	Mineral Fiber ASTM C 547, Class 2, ASTM C 592 Class 1, or ASTM C 612 Class 3	NA	NA	100	100	125
	Calcium Silicate ASTM C 533 Type I or II	NA	NA	100	100	100
	Mineral Fiber/ Cellular Glass Composite:					
	Mineral Fiber ASTM C 547 Class 2 ASTM C 592 Class 1, or ASTM C 612 Class 3	25	25	25	25	50
	Cellular Glass ASTM C 552, Type II	50	50	50	50	50
Boiler Stack (316 to 427°C)	Mineral Fiber ASTM C 547 Class 3, ASTM C 592 Class 1, or ASTM C 612 Class 3	NA	NA	100	100	150
	Calcium Silicate ASTM C 533 Type I or II	NA	NA	100	100	150
	Mineral Fiber/ Cellular Glass Composite:					

TABLE 7
Insulation and Thickness (mm and °C) for
Boiler Stack and Diesel Engine Exhaust Pipe

Service & Surface Temperature Range (Degrees C)	Material	Outside Diameter (mm) 6-32	40-80	90-125	150-250	280-900
	Mineral Fiber ASTM C 547, Class 2, ASTM C 592 Class 1, or ASTM C 612 Class 3	50	50	50	80	100
	Cellular Glass ASTM C 552, Type II	50	50	50	50	50
Diesel Engine Exhaust (Up to 371°C)	Calcium Silicate ASTM C 533 Type I or II	80	90	100	100	100
	Cellular Glass ASTM C 552, Type II	65	90	100	115	150

TABLE 7
Insulation and Thickness (Inches and °F) for
Boiler Stack and Diesel Engine Exhaust Pipe

Service & Surface Temperature Range (Degrees F)	Material	Outside Diameter (Inches) 1/4-1-1/4	1-1/2-3	3-1/2-5	6-10	11-36
Boiler Stack (Up to 400° F)	Mineral Fiber ASTM C 553 Class B-3, ASTM C 547 Class 1, or ASTM C 612 Class 1	NA	NA	3	3.5	4
	Calcium Silicate ASTM C 533, Type 1	NA	NA	3	3.5	4
	Cellular Glass ASTM C 552, Type II	1.5	1.5	1.5	2	2.5
Boiler Stack	Mineral Fiber	NA	NA	4	4	5

TABLE 7
Insulation and Thickness (Inches and °F) for
Boiler Stack and Diesel Engine Exhaust Pipe

Service & Surface Temperature Range (Degrees F)	Material	Outside Diameter (Inches) 1/4-1-1/4	1-1/2-3	3-1/2-5	6-10	11-36
(401 to 600°F)	ASTM C 547, Class 2, ASTM C 592 Class 1, or ASTM C 612 Class 3					
	Calcium Silicate ASTM C 533 Type I or II	NA	NA	4	4	4
	Mineral Fiber/ Cellular Glass Composite:					
	Mineral Fiber ASTM C 547 Class 2 ASTM C 592 Class 1, or ASTM C 612 Class 3	1	1	1	1	2
	Cellular Glass ASTM C 552, Type II	2	2	2	2	2
Boiler Stack (601 to 800°F)	Mineral Fiber ASTM C 547 Class 3, ASTM C 592 Class 1, or ASTM C 612 Class 3	NA	NA	4	4	6
	Calcium Silicate ASTM C 533 Type I or II	NA	NA	4	4	6
	Mineral Fiber/ Cellular Glass Composite:					
	Mineral Fiber ASTM C 547, Class 2, ASTM C 592 Class 1, or ASTM C 612 Class 3	2	2	2	3	4

TABLE 7
Insulation and Thickness (Inches and °F) for
Boiler Stack and Diesel Engine Exhaust Pipe

Service & Surface Temperature Range (Degrees F)	Material	Outside Diameter (Inches) 1/4-1-1/4	1-1/2-3	3-1/2-5	6-10	11-36
	Cellular Glass ASTM C 552, Type II	2	2	2	2	2
Diesel Engine Exhaust (Up to 700°F)	Calcium Silicate ASTM C 533 Type I or II	3	3.5	4	4	4
	Cellular Glass ASTM C 552, Type II	2.5	3.5	4	4.5	6

3.4.3.3 Insulation of Pumps

Insulate pumps by forming a box around the pump housing. The box shall be constructed by forming the bottom and sides using joints that do not leave raw ends of insulation exposed. Bottom and sides shall be banded to form a rigid housing that does not rest on the pump. Joints between top cover and sides shall fit tightly. The top cover shall have a joint forming a female shiplap joint on the side pieces and a male joint on the top cover, making the top cover removable. Two coats of Class I adhesive shall be applied over insulation, including removable sections, with a layer of glass cloth embedded between the coats. A parting line shall be provided between the box and the removable sections allowing the removable sections to be removed without disturbing the insulation coating. The total dry thickness of the finish shall be 2.0 mm 1/16 inch. Caulking shall be applied to parting line of the removable sections and penetrations.

3.4.3.4 Other Equipment

a. Insulation shall be formed or fabricated to fit the equipment. To ensure a tight fit on round equipment, edges shall be beveled and joints shall be tightly butted and staggered.

b. Insulation shall be secured in place with bands or wires at intervals as recommended by the manufacturer but not greater than 300 mm 12 inch centers except flexible elastomeric cellular which shall be adhered. Insulation corners shall be protected under wires and bands with suitable corner angles.

c. On high vibration equipment, cellular glass insulation shall be set in a coating of bedding compound as recommended by the manufacturer, and joints shall be sealed with bedding compound. Mineral fiber joints shall be filled with finishing cement.

d. Insulation on heads of heat exchangers shall be removable. The removable section joint shall be fabricated using a male-female shiplap type joint. Entire surface of the removable section shall

be finished as specified.

e. Exposed insulation corners shall be protected with corner angles.

f. On equipment with ribs, such as boiler flue gas connection, draft fans, and fly ash or soot collectors, insulation shall be applied over 150 x 150 mm 6 x 6 inch by 12 gauge welded wire fabric which has been cinched in place, or if approved by the Contracting Officer, spot welded to the equipment over the ribs. Insulation shall be secured to the fabric with J-hooks and 50 x 50 mm 2 x 2 inch washers or shall be securely banded or wired in place on 300 mm 12 inch (maximum) centers.

g. On equipment handling media above 316 degrees C 600 degrees F, insulation shall be applied in two or more layers with joints staggered.

h. Upon completion of installation of insulation, penetrations shall be caulked. Two coats of adhesive shall be applied over insulation, including removable sections, with a layer of glass cloth embedded between the coats. The total dry thickness of the finish shall be 2.0 mm 1/16 inch. Caulking shall be applied to parting line between equipment and removable section insulation.

3.4.4 Equipment Handling Dual Temperature Media

Below and above 16 degrees C 60 degrees F: equipment handling dual temperature media shall be insulated as specified for cold equipment.

3.4.5 Equipment Exposed to Weather

3.4.5.1 Installation

Equipment exposed to weather shall be insulated and finished in accordance with the requirements for ducts exposed to weather in paragraph DUCT INSULATION INSTALLATION.

3.4.5.2 Optional Panels

At the option of the Contractor, prefabricated metal insulation panels may be used in lieu of the insulation and finish previously specified. Thermal performance shall be equal to or better than that specified for field applied insulation. Panels shall be the standard catalog product of a manufacturer of metal insulation panels. Fastenings, flashing, and support system shall conform to published recommendations of the manufacturer for weatherproof installation and shall prevent moisture from entering the insulation. Panels shall be designed to accommodate thermal expansion and to support a 1112 N 250 pound walking load without permanent deformation or permanent damage to the insulation. Exterior metal cover sheet shall be aluminum and exposed fastenings shall be stainless steel or aluminum.

-- End of Section --