
USACE / NAVFAC / AFCEA / NASA UFGS-23 07 00 (August 2010)

Preparing Activity: USACE Superseding
UFGS-23 07 00 (November 2009)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2012

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DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING

SECTION 23 07 00

THERMAL INSULATION FOR MECHANICAL SYSTEMS

08/10

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SECTION 23 07 00

THERMAL INSULATION FOR MECHANICAL SYSTEMS 08/10

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.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

PART 1 GENERAL

NOTE: Show the following information 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 or 8-ply vapor barrier jacket are to be used on interior piping;
4. Pumps to be insulated and encased in 20 gauge boxes; and

5. Heat exchange temperatures.

1.1 REFERENCES

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.

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 - IP (2010; INT 1 2011; Errata 2011, Errata 2011; INT 2-12 2011) Energy Standard for Buildings Except Low-Rise Residential Buildings

ASHRAE 90.1 - SI (2010; Errata 2011; INT 2-12 2011) Energy Standard for Buildings Except Low-Rise Residential Buildings

ASHRAE 90.2 (2007; Addendum B 2010) Energy Efficient Design of Low-Rise Residential Buildings

ASTM INTERNATIONAL (ASTM)

ASTM A167 (2011) Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip

ASTM A240/A240M (2011a) Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure

Vessels and for General Applications

ASTM A580/A580M	(2008) Standard Specification for Stainless Steel Wire
ASTM B209	(2010) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B209M	(2010) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate (Metric)
ASTM C1126	(2011e1) Standard Specification for Faced or Unfaced Rigid Cellular Phenolic Thermal Insulation
ASTM C1136	(2010) Standard Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation
ASTM C1290	(2011) Standard Specification for Flexible Fibrous Glass Blanket Insulation Used to Externally Insulate HVAC Ducts
ASTM C1427	(2007e1) Specification for Preformed Flexible Cellular Polyolefin Thermal Insulation in Sheet and Tubular Form
ASTM C1534	(2007e1) Standard Specification for Flexible Polymeric Foam Sheet Insulation Used as a Thermal and Sound Absorbing Liner for Duct Systems
ASTM C195	(2007) Standard Specification for Mineral Fiber Thermal Insulating Cement
ASTM C449	(2007) Standard Specification for Mineral Fiber Hydraulic-Setting Thermal Insulating and Finishing Cement
ASTM C533	(2011) Standard Specification for Calcium Silicate Block and Pipe Thermal Insulation
ASTM C534/C534M	(2008) Standard Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form
ASTM C547	(2011) Standard Specification for Mineral Fiber Pipe Insulation
ASTM C552	(2007) Standard Specification for Cellular Glass Thermal Insulation
ASTM C553	(2011) Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
ASTM C591	(2011) Standard Specification for Unfaced Preformed Rigid Cellular Polyisocyanurate

Thermal Insulation

ASTM C592	(2010) Standard Specification for Mineral Fiber Blanket Insulation and Blanket-Type Pipe Insulation (Metal-Mesh Covered) (Industrial Type)
ASTM C610	(2010) Standard Specification for Molded Expanded Perlite Block and Pipe Thermal Insulation
ASTM C612	(2010) Mineral Fiber Block and Board Thermal Insulation
ASTM C647	(2008) Properties and Tests of Mastics and Coating Finishes for Thermal Insulation
ASTM C665	(2006) Mineral-Fiber Blanket Thermal Insulation for Light Frame Construction and Manufactured Housing
ASTM C795	(2008) Standard Specification for Thermal Insulation for Use in Contact with Austenitic Stainless Steel
ASTM C916	(1985; R 2007) Standard Specification for Adhesives for Duct Thermal Insulation
ASTM C920	(2011) Standard Specification for Elastomeric Joint Sealants
ASTM C921	(2010) Standard Practice for Determining the Properties of Jacketing Materials for Thermal Insulation
ASTM D882	(2010) Tensile Properties of Thin Plastic Sheeting
ASTM E2231	(2009) Specimen Preparation and Mounting of Pipe and Duct Insulation Materials to Assess Surface Burning Characteristics
ASTM E2336	(2004; R 2009) Standard Test Methods for Fire Resistive Grease Duct Enclosure Systems
ASTM E84	(2011b) Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM E96/E96M	(2010) Standard Test Methods for Water Vapor Transmission of Materials

FM GLOBAL (FM)

FM APP GUIDE (updated on-line) Approval Guide
<http://www.approvalguide.com/>

GREENGUARD ENVIRONMENTAL INSTITUTE (GEI)

GEI Greenguard Standards for Low Emitting Products

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 2758 (2001) Paper - Determination of Bursting Strength

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

MSS SP-69 (2003) Pipe Hangers and Supports - Selection and Application (ANSI Approved American National Standard)

MIDWEST INSULATION CONTRACTORS ASSOCIATION (MICA)

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

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 90A (2012) Standard for the Installation of Air Conditioning and Ventilating Systems

NFPA 90B (2012) Standard for the Installation of Warm Air Heating and Air Conditioning Systems

NFPA 96 (2011) Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations

SCIENTIFIC CERTIFICATION SYSTEMS (SCS)

SCS Scientific Certification Systems (SCS) Indoor Advantage

TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY (TAPPI)

TAPPI T403 OM (2010) Bursting Strength of Paper

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-A-24179 (1969; Rev A; Am 2 1980; Notice 1 1987) Adhesive, Flexible Unicellular-Plastic Thermal Insulation

MIL-A-3316 (1987; Rev C; Am 2 1990) Adhesives, Fire-Resistant, Thermal Insulation

UNDERWRITERS LABORATORIES (UL)

UL 723 (2008; Reprint Sep 2010) Test for Surface Burning Characteristics of Building Materials

1.2 SYSTEM DESCRIPTION

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 Sections 33 61 13 PRE-ENGINEERED UNDERGROUND HEAT DISTRIBUTION SYSTEM, 33 61 15 HEAT DISTRIBUTION SYSTEMS IN CONCRETE TRENCHES, 33 61 00 PREFABRICATED UNDERGROUND HEATING/COOLING DISTRIBUTION SYSTEM, and 33 60 02 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).

1.2.1 General

Provide field-applied insulation and accessories on mechanical systems 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 33 61 13 PRE-ENGINEERED UNDERGROUND HEAT DISTRIBUTION SYSTEM, Section 33 61 15 HEAT DISTRIBUTION SYSTEMS IN CONCRETE TRENCHES, Section 33 60 02 ABOVEGROUND HEAT DISTRIBUTION SYSTEM, and Section 33 61 00 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.

1.2.2 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 E84. Flame spread, and smoke developed indexes, shall be determined by ASTM E84 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 E2231. Insulation materials located exterior to the building perimeter are not required to be fire rated.

1.2.3 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

1.3 SUBMITTALS

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project.

The Guide Specification technical editors have designated those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, 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.

In 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.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

Submit the three SD types, SD-02 Shop Drawings, SD-03 Product Data, and SD-08 Manufacturer's Instructions at the same time for each system.

SD-02 Shop Drawings

NOTE: For NAVFAC LANT projects, delete the
requirement for this SD-02 Shop Drawing Submittal.

MICA Plates[; G][; G, [____]]
Pipe Insulation Systems and Associated Accessories
Duct Insulation Systems and Associated Accessories
Equipment Insulation Systems and Associated Accessories

SD-03 Product Data

Certification
Pipe Insulation Systems[; G][; G, [____]]
Duct Insulation Systems[; G][; G, [____]]
Equipment Insulation Systems[; G][; G, [____]]

SD-04 Samples

Thermal Insulation[; G][; G, [____]]

SD-08 Manufacturer's Instructions

Pipe Insulation Systems[; G][; G, [____]]
Duct Insulation Systems[; G][; G, [____]]
Equipment Insulation Systems[; G][; G, [____]]

1.4 QUALITY ASSURANCE

1.4.1 Installer Qualification

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

1.4.2 Sustainable Design Certification

Product shall be third party certified by GEI Greenguard Indoor Air Quality Certified, SCS Scientific Certification Systems Indoor Advantage or equal. Certification shall be performed annually and shall be current.

1.5 DELIVERY, STORAGE, AND HANDLING

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. 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.

PART 2 PRODUCTS

2.1 STANDARD PRODUCTS

Provide materials which are the standard products of manufacturers regularly engaged in the manufacture of such products and that essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening. Submit 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 including adhesives, sealants and jackets for each mechanical system requiring insulation shall be included. The product data must be copyrighted, have an identifying or publication number, and shall have been published prior to the issuance date of this solicitation. Materials furnished under this section shall be submitted together in a booklet and in conjunction with the MICA plates booklet (SD-02). Annotate the product data to indicate which MICA plate is applicable. Provide insulation systems in accordance with the approved MICA National Insulation Standards plates as supplemented by this specification. 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. Insulation shall be CFC and HCFC free.

2.2 MATERIALS

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.

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

Provide insulation that meets or exceed the requirements of [ASHRAE 90.1 - SIASHRAE 90.1 - IP][ASHRAE 90.2]. 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 C795 requirements. Calcium silicate shall not be used on chilled or cold water systems. Materials shall be asbestos free and conform to the following: Flexible Elastomeric: Closed-cell, foam- or expanded-rubber materials containing anti-microbial additive. Comply with ASTM C534/C534M,

Type I, Grade 1, for tubular materials and Type II, Grade 1, for sheet materials. Provide product recognized under [UL 94](#) and listed in [FM APP GUIDE](#).

2.2.1 Adhesives

2.2.1.1 Acoustical Lining Insulation Adhesive

Adhesive shall be a nonflammable, fire-resistant adhesive conforming to [ASTM C916](#), Type I.

2.2.1.2 Mineral Fiber Insulation Cement

Cement shall be in accordance with [ASTM C195](#).

2.2.1.3 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 E84](#). 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 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. Submit and display, after approval of materials, actual sections of installed systems, properly insulated in accordance with the specification requirements. 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.

- a. [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.
- b. [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.

2.2.2 Contact Adhesive

Adhesives may be any of, but not limited to, the neoprene 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 E84](#). 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. Flexible Elastomeric and Polyolefin Adhesive: Comply with [MIL-A-24179](#), Type II, Class I. Provide product recognized under [UL 94](#) and listed in [FM APP GUIDE](#).

2.2.3 Caulking

[ASTM C920](#), Type S, Grade NS, Class 25, Use A.

2.2.4 Corner Angles

2.2.4.1 General

Nominal [0.406 mm](#) [0.016 inch](#) aluminum [25 by 25 mm](#) [1 by 1 inch](#) with factory applied kraft backing. Aluminum shall be [ASTM B209M](#) [ASTM B209](#), Alloy 3003, 3105, or 5005.

2.2.4.2 Fittings

Fabricated Fittings are the prefabricated fittings for flexible elastomeric pipe insulation systems. Together with the flexible elastomeric tubes, they provide complete system integrity for retarding heat gain and controlling condensation drip from chilled-water and refrigeration systems. Flexible elastomeric, fabricated fittings provide thermal protection (0.25 k) and condensation resistance (0.05 Water Vapor Transmission factor).

2.2.5 Finishing Cement

[ASTM C449](#): Mineral fiber hydraulic-setting thermal insulating and finishing cement. All cements that may come in contact with Austenitic stainless steel must comply with [ASTM C795](#).

2.2.6 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 E84](#). Tape shall be [100 mm](#) [4 inch](#) wide rolls. Class 3 tape shall be [0.15 kg/square m](#) [4.5 ounces/square yard](#). Elastomeric Foam Tape: Black vapor-retarder foam tape with acrylic adhesive containing an anti-microbial additive.

2.2.7 Staples

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

Outward clinching type [monel] [ASTM A167, Type 304 or 316 stainless steel].

2.2.8 Jackets

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

2.2.8.1 Aluminum Jackets

Aluminum jackets shall be corrugated, embossed or smooth sheet, 0.406 mm 0.016 inch nominal thickness; ASTM B209M ASTM B209, Temper H14, Temper H16, Alloy 3003, 5005, or 3105. Corrugated aluminum jacket shall not be used outdoors. Aluminum jacket securing bands shall be Type 304 stainless steel, 0.396 mm 0.015 inch thick, 13 mm 1/2 inch wide for pipe under 300 mm 12 inch diameter and 19 mm 3/4 inch wide for pipe over 300 mm 12 inch and larger diameter. Aluminum jacket circumferential seam bands shall be 50.8 by 0.406 mm 2 by 0.016 inch aluminum matching jacket material. Bands for insulation below ground shall be 19 by 0.508 mm 3/4 by 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 Pittsburgh 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.

2.2.8.2 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 0.762 mm 0.030 inch.

2.2.8.3 Vapor Barrier/Weatherproofing Jacket

NOTE: Do not provide this material on Navy projects. Material greater than 8 ply is to be used for Army projects only.

Vapor barrier/weatherproofing jacket shall be laminated self-adhesive, greater than 3 plies standard grade, silver, white, black and embossed or greater than 8 ply (minimum 0.072 mm 2.9 mils adhesive); with 0.0000 permeability when tested in accordance with ASTM E96/E96M; heavy duty, white or natural; and UV resistant. Flexible Elastomeric exterior foam

with factory applied, UV Jacket made with a cold weather acrylic adhesive. Construction of laminate designed to provide UV resistance, high puncture, tear resistance and excellent WVT.

2.2.9 Vapor Retarder Required

NOTE: The functions of a vapor retarder/vapor barrier 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 barrier for use over insulation on pipes, ducts, or equipment operating at temperatures below ambient at least part of the time or wherever a vapor barrier is required. Type II vapor retarder is water vapor permeable and for use over pipes, ducts, or equipment operating above ambient temperatures or wherever a vapor barrier is not required.

ASTM C921, 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 C921, 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 E84.

2.2.9.1 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.

2.2.9.2 Vapor Retarder/Vapor Barrier Mastic Coatings

- a. The vapor barrier shall be self adhesive (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) greater than 3 plies standard grade, silver, white, black and embossed white jacket for use on hot/cold pipes. Less than 0.02 permeability when tested in accordance with ASTM E96/E96M. Meeting UL 723 or ASTM E84 flame and smoke requirements; UV resistant.
- b. 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 E96/E96M utilizing apparatus described in ASTM E96/E96M. The coating shall be a nonflammable, fire resistant type. All other application and service properties shall be in accordance with ASTM C647.

2.2.9.3 Laminated Film Vapor Retarder

ASTM C1136, 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 E84](#). Flexible Elastomeric exterior foam with factory applied UV Jacket. Construction of laminate designed to provide UV resistance, high puncture, tear resistance and excellent WVT.

2.2.9.4 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 in accordance with [ASTM D882](#), and a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with [ASTM E84](#).

2.2.9.5 Polyvinylidene Chloride Vapor Retarder Adhesive Tape

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

2.2.9.6 Vapor Barrier

The vapor barrier shall be greater than 3 ply self adhesive laminate -white vapor barrier jacket- superior performance (less than 0.0000 permeability when tested in accordance with [ASTM E96/E96M](#)). Vapor barrier shall meet [UL 723](#) or [ASTM E84](#) 25 flame and 50 smoke requirements; and UV resistant. Minimum burst strength [1.3 MPa](#) [185 psi](#) in accordance with [[TAPPI T403 OM](#)] [[ISO 2758](#)]. Tensile strength [0.12 kg/m](#) [68 lb/inch](#) width (PSTC-1000). Tape shall be as specified for laminated film vapor barrier above.

2.2.10 Vapor Retarder Not Required

[ASTM C921](#), 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 E84](#).

2.2.11 Wire

Soft annealed [ASTM A580/A580M](#) Type 302, 304 or 316 stainless steel, 16 or 18 gauge.

2.2.12 Insulation Bands

Insulation bands shall be [13 mm](#) [1/2 inch](#) wide; 26 gauge stainless steel.

2.2.13 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 E84](#).

2.3 PIPE INSULATION SYSTEMS

NOTE: Where the temperature of cold water entering a building is below the average dew point of the indoor ambient air, and where condensate drip will cause damage or create a hazard, the piping should be insulated to prevent condensation and a vapor barrier added per manufacturer's recommendations, if needed, whether piping is above or below ceilings.

Flexible elastomeric, 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 insulation, recommended minimum thickness is 25 mm (one inch).

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

Insulation materials shall conform to Table 1. Insulation thickness shall be as listed in Table 2 and meet or exceed the requirements of [ASHRAE 90.1 - SIASHRAE 90.1 - IP] [ASHRAE 90.2]. Insulation thickness shall be [13] [25] [] mm [1/2] [1] [] inch. Comply with EPA requirements in accordance with Section 01 62 35 RECYCLED / RECOVERED MATERIALS. Pipe insulation materials shall be limited to those listed herein and shall meet the following requirements:

2.3.1 Aboveground Cold Pipeline (-34 to 16 deg. C -30 to 60 deg. F)

NOTE: When it is necessary to insulate existing cold water systems or systems that must remain in operation, the Designer may consider using a mineral fiber insulation that meets ASTM C547, with an integral wicking material designed to remove condensed water. Follow manufacturer's recommendations for installation.

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

- a. Cellular Glass: ASTM C552, Type II, and Type III. Supply the insulation with manufacturer's recommended factory-applied jacket/vapor barrier.
- b. Flexible Elastomeric Cellular Insulation: ASTM C534/C534M, Grade 1, Type I or II. Type II shall have vapor retarder/vapor barrier skin on one or both sides of the insulation.
- c. Phenolic Insulation: ASTM C1126, Type III. Phenolic insulations shall comply with ASTM C795 and with the ASTM C665 paragraph Corrosiveness. Supply the insulation with manufacturer's recommended factory-applied

jacket/vapor barrier.

- d. Polyisocyanurate Insulation: ASTM C591, type I. Supply the insulation with manufacturer's recommended factory-applied vapor retarder/vapor barrier. Insulation with pre-applied adhesive shall not be used.
- e. Flexible Polyolefin Cellular Insulation: ASTM C1427, Grade 1 Type I or II.
- f. Mineral Fiber Insulation with Integral Wicking Material (MFIWM): ASTM C547. Install in accordance with manufacturer's instructions.

2.3.2 Aboveground Hot Pipeline (Above 16 deg. C 60 deg. F)

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

- a. Mineral Fiber: ASTM C547, Types I, II or III, supply the insulation with manufacturer's recommended factory-applied jacket.
- b. Calcium Silicate: ASTM C533, 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/vapor barrier.
- c. Cellular Glass: ASTM C552, Type II and Type III. Supply the insulation with manufacturer's recommended factory-applied jacket.
- d. Flexible Elastomeric Cellular Insulation: ASTM C534/C534M, Grade 1, Type I or II to 105 degrees C 220 degrees F service.
- e. Phenolic Insulation: ASTM C1126 Type III to 121 degrees C 250 degrees F service shall comply with ASTM C795. Supply the insulation with manufacturer's recommended factory-applied jacket/vapor barrier.
- f. Perlite Insulation: ASTM C610
- g. Polyisocyanurate Insulation: ASTM C591, Type 1, to 149 degrees C 300 degrees F service. Supply the insulation with manufacturer's recommended factory applied jacket/vapor barrier.
- h. Flexible Polyolefin Cellular Insulation: ASTM C1427, Grade 1 Type I or II to 93 degrees C 200 degrees F.

2.3.3 Above Ground Dual Temperature Pipeline

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/vapor barrier, 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 (Outdoors, Indoor - Exposed or Concealed) 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.

2.3.4 Below-ground Pipeline Insulation

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

2.3.4.1 Cellular Glass

ASTM C552, type II.

2.3.4.2 Polyisocyanurate

ASTM C591, Type 1, to 149 degrees C 300 degrees F.

2.4 DUCT INSULATION SYSTEMS

NOTE: For NAVFAC ML projects, delete option of the
following paragraph.

2.4.1 Duct Insulation

Provide factory-applied [cellular glass polyisocyanurate or phenolic foam][elastomeric insulation. Provide factory applied elastomeric closed cell or phenolic foam insulation according to manufacturer's recommendations for] 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.]

2.4.1.1 Rigid Insulation

Rigid mineral fiber in accordance with ASTM C612, Class 2 (maximum surface temperature 204 degrees C 400 degrees F), 48 kg/m3 3 pcf average, 38 mm 1-1/2 inch thick, Type IA, IB, II, III, and IV. [Alternately, minimum thickness may be calculated in accordance with [ASHRAE 90.2] [ASHRAE 90.1 - SIASHRAE 90.1 - IP].]

2.4.1.2 Blanket Insulation

NOTE: For NAVFAC ML, delete this paragraph.

Blanket flexible mineral fiber insulation conforming to ASTM C553, 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 C1290 Type III may be used. [Alternately, minimum thickness may be calculated in accordance with [ASHRAE 90.2] [ASHRAE 90.1 - SIASHRAE 90.1 - IP].]

2.4.2 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.

Insulation thickness shall be a minimum of 50 mm 2 inches, blocks or boards, either mineral fiber conforming to ASTM C612, Class 5, 320 kg/m3 20 pcf average [or calcium silicate conforming to ASTM C533, Type II. Provide vapor barrier for outside air connection to kitchen exhaust hood]. The enclosure materials and the grease duct enclosure systems shall meet testing requirements of ASTM E2336 for noncombustibility, fire resistance, durability, internal fire, and fire-engulfment with a through-penetration fire stop.

2.4.3 Acoustical Duct Lining

2.4.3.1 General

For ductwork indicated or specified in Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM to be acoustically lined, provide external insulation in accordance with this specification section and in addition to the acoustical duct lining. Do not use acoustical lining in place of duct wrap or rigid board insulation (insulation on the exterior of the duct).

2.4.3.2 Duct Liner

Flexible Elastomeric Acoustical and Conformable Duct Liner: Materials: Flexible Elastomeric Thermal, Acoustical and Conformable Insulation Compliance with ASTM C534/C534M Grade 1, Type II or ASTM C1534 and NFPA 90A or NFPA 90B.

2.4.4 Duct Insulation Jackets

2.4.4.1 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.

2.4.4.2 Metal Jackets

- a. Aluminum Jackets: ASTM B209M ASTM B209, 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 13 mm 1/2 inch.
- b. Stainless Steel Jackets: ASTM A167 or ASTM A240/A240M; 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 13 mm 1/2 inch.

2.4.4.3 Vapor Barrier/Weatherproofing Jacket

Vapor barrier/weatherproofing jacket shall be laminated self-adhesive (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) less than

0.0000 permeability, (greater than 3 ply, standard grade, silver, white, black and embossed or greater than 8 ply (minimum 0.072 mm 2.9 mils adhesive), heavy duty white or natural).

2.4.5 Weatherproof Duct Insulation

Provide [ASTM C591 Type I, polyurethane or polyisocyanate board insulation, minimum density of 27 kg/m3 1.7 pcf] [ASTM C552, cellular glass thermal insulation] [ASTM C534/C534M Grade 1, Type II, flexible elastomeric cellular insulation], and weatherproofing as specified in manufacturer's instruction. Multi-ply, Polymeric Blend Laminate Jacketing: Construction of laminate designed to provide UV resistance, high puncture, tear resistance and excellent WVT.

2.5 EQUIPMENT INSULATION SYSTEMS

Insulate equipment and accessories as specified in Tables 4 and 5. In outside locations, provide insulation 13 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. Submit a booklet containing manufacturer's published installation instructions for the insulation systems in coordination with the submitted MICA Insulation Std's plates booklet. Annotate their installation instructions to indicate which product data and which MICA plate are applicable. The instructions must be copyrighted, have an identifying or publication number, and shall have been published prior to the issuance date of this solicitation. A booklet is also required by paragraphs titled: Pipe Insulation Systems and Duct Insulation Systems.

PART 3 EXECUTION

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 07 84 00 FIRESTOPPING. The protection of ducts at point of passage through firewalls must be in accordance with NFPA 90A and/or NFPA 90B. All other penetrations, such as piping, conduit, and wiring, through firewalls must be protected with a material or system of the same hourly rating that is listed by UL, FM, or a NRTL.

3.1.3 Painting and Finishing

Painting shall be as specified in Section 09 90 00 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. Flexible elastomeric cellular insulation shall not be used on surfaces greater than 105 degrees C 220 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 SYSTEMS INSTALLATION

Install pipe insulation systems in accordance with the approved MICA Insulation Stds plates as supplemented by the manufacturer's published installation instructions.

3.2.1 Pipe Insulation

3.2.1.1 General

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.

Pipe insulation shall be installed on aboveground hot and cold pipeline systems as specified below to form a continuous thermal retarder/barrier, 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.

3.2.1.2 Pipes Passing Through Walls, Roofs, and Floors

NOTE: Exterior wall and roof penetration details will be shown on the drawings. See Section 22 00 00 PLUMBING, GENERAL PURPOSE for additional information.

- a. Pipe insulation shall be continuous through the sleeve.
- b. An aluminum jacket or vapor barrier/weatherproofing - self adhesive jacket (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) less than 0.0000 permeability, greater than 3 ply standard grade, silver, white, black and embossed with factory applied moisture retarder shall be provided over the insulation wherever penetrations require sealing.
- c. Where pipes penetrate interior walls, the aluminum jacket or vapor

barrier/weatherproofing - self adhesive jacket (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) less than 0.0000 permeability, greater than 3 plies standard grade, silver, white, black and embossed 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 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 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, or factory insulated hangers (designed with a load bearing core) can be used.

- 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 22 00 00 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, prefabricated insulation pipe hangers, perlite above 27 degrees C 80 degrees 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 in accordance with 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 in accordance with 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 C1136, 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.

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.

In high abuse areas such as janitor closets and traffic areas in equipment rooms, kitchens, and mechanical rooms, [welded PVC] [stainless steel], aluminum or flexible laminate cladding (comprised of elastomeric, plastic or metal foil laminate) laminated self-adhesive (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) vapor barrier/weatherproofing jacket, - less than 0.0000 permeability; (greater than 3 ply, standard grade, silver, white, black and embossed) [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

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.

Flexible elastomeric 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). Flexible elastomeric 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.

In Tables 1 and 2, when it is necessary to insulate existing cold water systems or systems that must remain in operation, the Designer may consider using a mineral fiber insulation that meets ASTM C547, with an integral wicking material designed to remove condensed water. Follow manufacturer's recommendations for installation.

NOTE: For NAVFAC LANT 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 NAVFAC SE projects, use only cellular glass with vapor barrier for chilled water piping.

For NAVFAC PAC 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					
Service					
	Material	Specification	Type	Class	VR/VB Req'd
Chilled Water (Supply & Return, Dual Temperature Piping, 4.44 C 40 F nominal)					
	Cellular Glass	ASTM C552	II	2	No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Faced Phenolic Foam	ASTM C1126	III		Yes
	Polyisocyanurate	ASTM C591	I		Yes
	[Mineral Fiber with Wicking Material]	[ASTM C547]	[I]		[Yes]
Heating Hot Water Supply & Return, Heated Oil (Max 121 C 250 F)					
	Mineral Fiber	ASTM C547	I	1	No
	Calcium Silicate	ASTM C533	I		No
	Cellular Glass	ASTM C552	II	2	No
	Faced Phenolic Foam	ASTM C1126	III		Yes

TABLE 1					
Insulation Material for Piping					
Service					
	Material	Specification	Type	Class	VR/VB Req'd
	Perlite	ASTM C610			No
	Polyisocyanurate	ASTM C591	I		No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I	2	No
Cold Domestic Water Piping, Makeup Water & Drinking Fountain Drain Piping					
	Polyisocyanurate	ASTM C591	I		Yes
	Cellular Glass	ASTM C552	II	2	No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Faced Phenolic Foam	ASTM C1126	III		Yes
	Flexible Polyolefin Cellular	ASTM C1427	I		No
Hot Domestic Water Supply & Recirculating Piping (Max 93 C 200 F)					
	Mineral Fiber	ASTM C547	I	1	No
	Cellular Glass	ASTM C552	II	2	No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Faced Phenolic Foam	ASTM C1126	III		Yes
	Polyisocyanurate	ASTM C591	I		No
Refrigerant Suction Piping (1.67 degrees C35 degrees F nominal)					
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Cellular Glass	ASTM C552	II	1	Yes
	Faced Phenolic Foam	ASTM C1126	III		Yes
	Polyisocyanurate	ASTM C591	I		Yes
Compressed Air Discharge, Steam and Condensate Return (94 to 121 Degrees C201 to 250 Degrees F					
	Cellular Glass	ASTM C552	II		No
	Mineral Fiber	ASTM C547	I	1	No
	Calcium Silicate	ASTM C533	I		No
	Faced Phenolic Foam	ASTM C1126	III		Yes
	Perlite	ASTM C610			No
	Polyisocyanurate	ASTM C591	I		No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I	2	No

TABLE 1					
Insulation Material for Piping					
Service					
	Material	Specification	Type	Class	VR/VB Req'd
Exposed Lavatory Drains, Exposed Domestic Water Piping & Drains to Areas for Handicapped Personnel					
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Flexible Polyolefin Cellular	ASTM C1427	I		No
Horizontal Roof Drain Leaders (Including Underside of Roof Drain Fittings)					
	Polyisocyanurate	ASTM C591	I		Yes
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Faced Phenolic Foam	ASTM C1126	III		Yes
	Cellular Glass	ASTM C552	III		Yes
Condensate Drain Located Inside Building					
	Polyisocyanurate	ASTM C591	I		Yes
	Cellular Glass	ASTM C552	II	2	No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Faced Phenolic Foam	ASTM C1126	II		Yes
Medium Temperature Hot Water, Steam and Condensate (122 to 176 Degrees C 251 to 350 Degrees F)					
	Mineral Fiber	ASTM C547	I	1	No
	Calcium Silicate	ASTM C533	I		No
	Cellular Glass	ASTM C552	I or II		No
	Perlite	ASTM C610			No
	Polyisocyanurate	ASTM C591	I		No
High Temperature Hot Water & Steam (177 to 371 Degrees C 351 to 700 Degrees F)					
	Mineral Fiber	ASTM C547	I	2	No
	Calcium Silicate	ASTM C533	I		No
	Perlite	ASTM C610			No
	Cellular Glass	ASTM C552			No
	Polyisocyanurate	ASTM C591	I		No
Brine Systems Cryogenics (-34 to -18 Degrees C -30 to 0 Degrees F)					
	Cellular Glass	ASTM C552	II	2	No

TABLE 1					
Insulation Material for Piping					
Service					
	Material	Specification	Type	Class	VR/VB Req'd
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Faced Phenolic Foam	ASTM C1126	III		Yes
	Polyisocyanurate	ASTM C591	I		Yes
Brine Systems Cryogenics (-18 to 1.11 Degrees C 0 to 34 Degrees F)					
	Cellular Glass	ASTM C552	II	2	No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Faced Phenolic Foam	ASTM C1126	III		Yes
	Polyisocyanurate	ASTM C591	I		Yes
Note: VR/VB = Vapor Retarder/Vapor Barrier					

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.

Flexible elastomeric, 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). Flexible elastomeric recommended minimum thickness is 25mm (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 C680, 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 NAVFAC LANT 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 jobs located at Cherry Point and Camp LeJeune North Carolina, use flexible elastomeric or rigid cellular phenolic insulation on cold water piping. Provide flexible elastomeric, cellular glass or rigid polyisocyanurate preformed pipe insulation for chilled water piping and chilled-hot water piping.

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

For NAVFAC PAC 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/inch) 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 criterion, the ambient temperature and relative humidity must be stated.						
Service						
	Material	Tube And Pipe Size (mm) (inch)				
		<25<1	25-<40 1-<1.5	40-<100 1.5-<4	100-<200 4-<8	> or = 200>8
[Chilled Water (Supply & Return, Dual Temperature Piping, 4.44 Degrees C 40 Degrees F nominal)]						
	Cellular Glass	401.5	502	502	652.5	803
	Faced Phenolic Foam	251	251	251	401.5	502
	Polyisocyanurate	251	251	251	251	251
	Mineral Fiber with Wicking Material	251	401.5	401.5	502	502
	Flexible Elastomeric Cellular	251	251	251	N/A	N/A
[Chilled Water (Supply & Return, Dual Temperature Piping, 4.44 Degrees C 40 Degrees F nominal)]						
	Cellular Glass	401.5	401.5	401.5	401.5	502
	Flexible Elastomeric Cellular	251	251	251	N/A	N/A
	Faced Phenolic Foam	251	251	251	251	401.5
	Mineral Fiber with Wicking Material	251	401.5	401.5	502	502
Heating Hot Water Supply & Return, Heated Oil (Max 121 C 250 F)						
	Mineral Fiber	401.5	401.5	502	502	502
	Calcium Silicate	652.5	652.5	803	803	803
	Cellular Glass	502	652.5	753	803	803
	Perlite	652.5	652.5	803	803	803
	Polyisocyanurate	251	251	401.5	401.5	401.5
	Flexible Elastomeric Cellular	251	251	251	N/A	N/A
Cold Domestic Water Piping, Makeup Water & Drinking Fountain Drain Piping						
	Cellular Glass	401.5	401.5	401.5	401.5	401.5

TABLE 2						
Piping Insulation Thickness (mm/inch) 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 criterion, the ambient temperature and relative humidity must be stated.						
Service						
	Material	Tube And Pipe Size (mm) (inch)				
		<25<1	25-<40 1-<1.5	40-<100 1.5-<4	100-<200 4-<8	> or = 200>8
	Flexible Elastomeric Cellular	251	251	251	N/A	N/A
	Faced Phenolic Foam	251	251	251	251	251
	Polyisocyanurate	251	251	251	251	251
Hot Domestic Water Supply & Recirculating Piping (Max 93 C 200 F)						
	Mineral Fiber	251	251	251	401.5	401.5
	Cellular Glass	401.5	401.5	401.5	502	502
	Flexible Elastomeric Cellular	251	251	251	N/A	N/A
	Polyisocyanurate	251	251	251	251	401.5
Refrigerant Suction Piping (1.67 degrees C 35 degrees F nominal)						
	Flexible Elastomeric Cellular	251	251	251	N/A	N/A
	Cellular Glass	401.5	401.5	401.5	401.5	401.5
	Faced Phenolic Foam	251	251	251	251	251
	Polyisocyanurate	251	251	251	251	251
Compressed Air Discharge, Steam and Condensate Return (94 to 121 Degrees C 201 to 250 Degrees F)						
	Mineral Fiber	401.5	401.5	502	502	502
		401.5 *	502*	652.5*	803*	903.5*
	Calcium Silicate	652.5	803	1004	1004	1154.5
	Cellular Glass	502	652.5	803	803	803
	Perlite	652.5	803	1004	1004	1154.5
	Polyisocyanurate	401.5	401.5	502	502	502

TABLE 2						
Piping Insulation Thickness (mm/inch) 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 criterion, the ambient temperature and relative humidity must be stated.						
Service						
	Material	Tube And Pipe Size (mm) (inch)				
		<25<1	25-<40 1-<1.5	40-<100 1.5-<4	100-<200 4-<8	> or = 200>8
	Flexible Elastomeric Cellular	251	251	251	N/A	N/A
Exposed Lavatory Drains, Exposed Domestic Water Piping & Drains to Areas for Handicapped Personnel						
	Flexible Elastomeric Cellular	130.5	130.5	130.5	130.5	130.5
Horizontal Roof Drain Leaders (Including Underside of Roof Drain Fittings)						
	Cellular Glass	401.5	401.5	401.5	401.5	401.5
	Flexible Elastomeric Cellular	251	251	251	N/A	N/A
	Faced Phenolic Foam	251	251	251	251	251
	Polyisocyanurate	251	251	251	251	251
Condensate Drain Located Inside Building						
	Cellular Glass	401.5	401.5	401.5	401.5	401.5
	Flexible Elastomeric Cellular	251	251	251	N/A	N/A
	Faced Phenolic Foam	251	251	251	251	251
Medium Temperature Hot Water, Steam and Condensate (122 to 176 Degrees C 251 to 350 Degrees F)						
	Mineral Fiber	401.5	803	803	1004	1004
		652.5 *	80*	903.5*		
	Calcium Silicate	652.5	903.5	1154.5	1154.5	1255
	Perlite	652.5	903.5	1154.5	1154.5	1255
	Flexible Elastomeric Cellular	251	251	251	N/A	N/A
High Temperature Hot Water & Steam (177 to 371 Degrees C 351 to 700 Degrees F)						
	Mineral Fiber	652.5	803	803	1004	1004

TABLE 2						
Piping Insulation Thickness (mm/inch) 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 criterion, the ambient temperature and relative humidity must be stated.						
Service						
	Material	Tube And Pipe Size (mm) (inch)				
		<25<1	25-<40 1-<1.5	40-<100 1.5-<4	100-<200 4-<8	> or = 200>8
	Calcium Silicate	1004	1154.5	1506	1506	1506
	Perlite	1004	1154.5	1506	1506	1506
	Polyisocyanurate	251	251	251	251	251
Brine Systems Cryogenics (-34 to -18 Degrees C-30 to 0 Degrees F)						
	Cellular Glass	652.5	652.5	803	803	903.5
	Flexible Elastomeric Cellular	251	251	N/A	N/A	N/A
	Faced Phenolic Foam	401.5	401.5	502	502	502
	Polyisocyanurate	401.5	401.5	502	502	502
Brine Systems Cryogenics (-18 to 1.11 Degrees C 0 to 34 Degrees F)						
	Cellular Glass	502	502	502	652.5	803
	Flexible Elastomeric Cellular	251	251	251	N/A	N/A
	Faced Phenolic Foam	251	251	251	401.5	401.5
	Polyisocyanurate	251	251	251	401.5	401.5

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 in accordance with 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. Make-up water.
- b. Horizontal and vertical portions of interior roof drains.
- c. Refrigerant suction lines.
- d. Chilled water.
- e. Dual temperature water, i.e. HVAC hot/chilled water.
- f. Air conditioner condensate drains.
- g. Brine system cryogenics
- h. Exposed lavatory drains and domestic water lines serving plumbing fixtures for handicap persons.

[i. Domestic cold and chilled drinking water.]

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 judgment 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 UFC 3-400-02. 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 UFC 3-410-01FA or UFC 3-410-02A. 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 UFC 3-400-02.)

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 Factory or Field applied Jacket

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/vapor barrier or field applied seal welded PVC jacket or greater than 3 ply laminated self-adhesive (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) vapor barrier/weatherproofing jacket - less than 0.0000 permeability, standard grade, silver, white, black and embossed for use with Mineral Fiber, Cellular Glass, Phenolic Foam, and Polyisocyanurate Foam Insulated Pipe. Insulation inside the building, to be protected with an aluminum jacket or greater than 3ply vapor barrier/weatherproofing self-adhesive (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) product, less than 0.0000 permeability, standard grade, Embossed Silver, White & Black, shall have the insulation and vapor retarder jacket installed as specified herein. The aluminum jacket or greater than 3ply vapor barrier/weatherproofing self-adhesive (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) product, less than 0.0000 permeability, standard grade, embossed silver, White & Black, 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 or greater than 3ply vapor barrier/weatherproofing self-adhesive (minimum 0.05 mm 2 mils adhesive,

0.075 mm 3 mils embossed) product, less than 0.0000 permeability, standard grade, embossed silver, white & black, shall be provided for 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, greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape 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 in accordance with 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 or greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape. All seams, except those on factory self-seal systems shall be coated with vapor retarder coating or PVDC adhesive tape or greater than 3 ply laminate jacket - less than 0.0000 perm 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 or greater than 3 ply laminate jacket - less than 0.0000 perm 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 or greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape or greater than 3 ply laminate jacket - less than 0.0000 perm 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 or greater than 3 ply laminate jacket - less than 0.0000 perm 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". Submit a booklet containing completed MICA Insulation Stds plates detailing each insulating system for each pipe, duct, or equipment insulating system, after approval of materials and prior to applying insulation.
 - (1) The MICA plates shall detail the materials to be installed and the specific insulation application. Submit all MICA plates required showing the entire insulating system, including plates required to show insulation penetrations, vessel bottom and top heads, legs, and skirt insulation as applicable. The MICA plates shall present all variations of insulation systems including locations, materials, vaporproofing, jackets and insulation accessories.
 - (2) If the Contractor elects to submit detailed drawings instead of edited MICA Plates, the detail drawings shall be technically equivalent to the edited MICA Plate submittal.
- 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 or greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape or two coats of vapor retarder coating with a minimum total thickness of 2 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 either greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape, standard grade, silver, white, black and embossed or 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

3.2.3.1 General Requirements

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 in accordance with 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 I jacket or field applied aluminum where required or seal welded PVC.

3.2.3.2 Insulation for Fittings and Accessories

- a. General. 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. Insulation shall be marked showing the location of unions, strainers, check valves and other components that would otherwise be hidden from view by the insulation.
- b. Precut or Preformed. Precut or preformed insulation shall be placed around all fittings and accessories. Insulation shall be the same insulation as the pipe insulation, including same density, thickness, and thermal conductivity.

c. Rigid Preformed. 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".

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, a laminated self-adhesive (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) vapor barrier/weatherproofing jacket - less than 0.0000 permeability (greater than 3 ply, standard grade, silver, white, black and embossed 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 laminated self-adhesive (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) vapor barrier/weatherproofing jacket - less than 0.0000 permeability, (greater than 3 ply, standard grade, silver, white, black and embossed, and UV resistant.

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 fibrous 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. Vapor barrier - less than 0.0000 permeability self adhesive (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) jacket greater than 3 ply, standard grade, silver, white, black and embossed or greater than 8 ply (minimum 0.072 2.9 mils adhesive), heavy duty, white or natural). Application procedures shall match the 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 DUCT INSULATION SYSTEMS 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.

Install duct insulation systems in accordance with the approved MICA Insulation Stds plates as supplemented by the manufacturer's published installation instructions.

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

NOTE: The following tables are adapted from ASHRAE 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.

Table 3				
Minimum Duct Insulation				
	Cooling		Heating	
Duct Location	Annual Cooling Degree Days Base 18 C 65 F	Insulation R-Value (sm K)/W (h sf F)/Btu	Annual Heating Degree Days Base 18 C 65 F	Insulation R-Value (sm K)/W (h sf F)/Btu
Exterior of Building	<260500	0.583.3	<8161500	0.583.3
	260 - 621500 - 1150	0.885.0	816 - 2482 1500 - 4500	0.885.0
	622 - 1093 1151 - 2000	1.146.5	2483 - 4149 4501 - 7500	1.146.5
	>10932000	1.418.0	>41497500	1.418.0
	Temperature Difference	Insulation R-Value (sm K)/W (h sf F)/Btu	Temperature Difference	Insulation R-Value (sm K)/W (h sf F)/Btu

Table 3				
Minimum Duct Insulation				
	Cooling		Heating	
Inside building envelope or in unconditioned spaces	<815	None required	<815	None required
	8 <TD <2215 <TD <40	0.583.3	8 <TD <2215 <TD <40	0.583.3
	22 <TD40 <TD	0.885.0	22 <TD40 <TD	0.885.0
<p>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 C518 at a mean temperature of 24 degrees C 75 drgrees 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 runouts to terminal devices less than 3 m10 feet in length need not exceed 0.58 (sm K)/W3.3 (h sf F)/Btu. Unconditioned spaces include crawlspaces and attics.</p>				

Duct insulation thickness shall be in accordance with Table 4.

Table 4 - Minimum Duct Insulation (mm) (inches)	
Cold Air Ducts	502.0
Relief Ducts	401.5
Fresh Air Intake Ducts	401.5
Warm Air Ducts	502.0
Relief Ducts	401.5
Fresh Air Intake Ducts	401.5

3.3.2 Insulation and Vapor Retarder/Vapor Barrier for Cold Air Duct

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/vapor barrier 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/vapor barrier jacket coating finish as specified, the total field applied dry film thickness shall be approximately 2 mm 1/16 inch. Insulation on all concealed duct shall be provided with a

factory-applied Type I or II vapor retarder/vapor barrier 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/vapor barrier shall cover the collar, neck, and any un-insulated surfaces of diffusers, registers and grills. Vapor retarder/vapor barrier materials shall be applied to form a complete unbroken vapor seal over the insulation. Sheet Metal Duct shall be sealed in accordance with Section 23 00 00 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/vapor barrier 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. Where mechanical fasteners are used, self-locking washers shall be installed and the pin trimmed 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 or greater than 3 ply laminate (minimum 0.05 mm 2 mils adhesive, 0.075 3 mils embossed) - less than 0.0000 perm 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 or greater than 3 ply laminate (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) - less than 0.0000 perm 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 greater than 3 ply laminate (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) - less than 0.0000 perm 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/barrier 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 and 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 in accordance with 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 trimmed 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

Laminated self-adhesive (minimum 0.05 mm 2 mils adhesive, 0.075 mm 3 mils embossed) vapor barrier/weatherproofing jacket - Less than 0.0000 permeability, (greater than 3 ply, standard grade, silver, white, black and embossed or greater than 8 ply, heavy duty, white and natural) membrane shall be applied overlapping material by 75 mm 3 inches no bands or caulking needed - see manufacturer's recommended installation instructions. 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 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 SYSTEMS INSTALLATION

Install equipment insulation systems in accordance with the approved MICA Insulation Stds plates as supplemented by the manufacturer's published installation instructions.

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.
- f. Duct Test/Balance Test Holes.

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:

TABLE 5		
Insulation Thickness for Cold Equipment (mm) (inches)		
Equipment handling media at indicated temperature		
	Material	Thickness (mm) (inches)
2 to 16 degrees C 35 to 60 degrees F		
	Cellular Glass	401.5
	Faced Phenolic Foam	401.5
	Flexible Elastomeric Cellular	251
	Polyisocyanurate Foam	251
	Flexible Polyolefin Cellular	251

TABLE 5		
Insulation Thickness for Cold Equipment (mm) (inches)		
Equipment handling media at indicated temperature		
	Material	Thickness (mm) (inches)
Minus 18 to 1 degree C 1 to 34 degrees F		
	Faced Phenolic Foam	401.5
	Polyisocyanurate Foam	401.5
	Cellular Glass	753
	Flexible Elastomeric Cellular	401.5
	Flexible Polyolefin Cellular	401.5
Minus 34 to minus 17 degrees C Minus 30 to 0 degrees F		
	Faced Phenolic Foam	401.5
	Polyisocyanurate Foam	451.75
	Cellular Glass	903.5
	Flexible Elastomeric Cellular	401.5
	Flexible Polyolefin Cellular	401.5

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 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 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 by 150 mm 6 by 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 by 50 mm 2 by 2 inches washers or shall be securely banded or wired in place on 300 mm 12 inch centers.

3.4.2.4 Vapor Retarder/Vapor Barrier

Upon completion of installation of insulation, penetrations shall be caulked. Two coats of vapor retarder coating or vapor barrier jacket 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 mm 1/16 inch. Caulking or vapor barrier tape 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:

TABLE 6		
Insulation Thickness for Hot Equipment (mm) (inches)		
Equipment handling steam or media at indicated pressure or temperature limit		
	Material	Thickness (mm) (inches)
103 kPa or 121 degrees C 15 psig or 250 degrees F		
	Rigid Mineral Fiber	502
	Flexible Mineral Fiber	502
	Calcium Silicate/Perlite	1004
	Cellular Glass	753
	Faced Phenolic Foam	401.5
	Flexible Elastomeric Cellular (<93 C <200 F)	251
	Polyisocyanurate Foam	251
1380 kPa or 204 degree C 200psig or 400 degrees F		
	Rigid Mineral Fiber	753
	Flexible Mineral Fiber	753
	Calcium Silicate/Perlite	1004
	Cellular Glass	1004
316 degrees C 600 degrees F		
	Rigid Mineral Fiber	1255
	Flexible Mineral Fiber	1506
	Calcium Silicate/Perlite	1506
	Cellular Glass	1506
316 degrees C 600 degrees F: Thickness necessary to limit the external temperature of the insulation to 50 C 120 F. 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 for Boiler Stack and Diesel Engine Exhaust Pipe						
Service & Surface Temperature Range (Degrees CF)						
	Material	Outside Diameter (mm) (Inches)				
		6 - 32 0.25 - 1.25	25 - 80 1 - 1.67	90-125 3.5-5	150 - 2506 - 10	> or = 280 - 90011 - 36
Boiler Stack (Up to 204 degrees C) (Up to 400 degrees F)						
	Mineral Fiber ASTM C553 Class B-3, ASTM C547 Class 1, or ASTM C612 Class 1	N/A	N/A	753	903.5	1004
	Calcium Silicate ASTM C533, Type 1	N/A	N/A	753	903.5	1004
	Cellular Glass ASTM C552, Type II	401.5	401.5	401.5	502	652.5
Boiler Stack (205 to 315 degrees C) (401 to 600 degrees F)						
	Mineral Fiber ASTM C547 Class 2, ASTM C592 Class 1, or ASTM C612 Class 3	N/A	N/A	1004	1004	1255
	Calcium Silicate ASTM C533, Type I or II	N/A	N/A	1004	1004	1004
	Mineral Fiber/Cellular Glass Composite:					
	Mineral Fiber ASTM C547 Class 2, ASTM C592 Class 1, or ASTM C612 Class 3	251	251	251	251	502

TABLE 7						
Insulation and Thickness for Boiler Stack and Diesel Engine Exhaust Pipe						
Service & Surface Temperature Range (Degrees CF)						
	Material	Outside Diameter (mm) (Inches)				
		6 - 32 0.25 - 1.25	25 - 80 1 - 1.67	90-125 3.5-5	150 - 2506 - 10	> or = 280 - 90011 - 36
	Cellular Glass ASTM C552, Type II	502	502	502	502	502
Boiler Stack (316 to 427 degrees C) (601 to 800 degrees F)						
	Mineral Fiber ASTM C547 Class 3, ASTM C592 Class 1, or ASTM C612 Class 3	N/A	N/A	1004	1004	1506
	Calcium Silicate ASTM C533, Type I or II	N/A	N/A	1004	1004	1506
	Mineral Fiber/Cellular Glass Composite:					
	Mineral Fiber ASTM C547 Class 2, ASTM C592 Class 1, or ASTM C612 Class 3	502	502	502	803	803
	Cellular Glass ASTM C552, Type II	502	502	502	502	502
Diesel Engine Exhaust (Up to 371 degrees C) (Up to 700 degrees F)						
	Calcium Silicate ASTM C533, Type I or II	803	903.5	1004	1004	1004
	Cellular Glass ASTM C552, Type II	652.5*	903.5	1004	1154.5	1506

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 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 by 150 mm 6 by 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 by 50 mm 2 by 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 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 --