

**SECTION 23 07 11
HVAC INSULATION**

SPEC WRITER NOTES:

1. Use this section only for NCA projects.
2. Delete between // // if not applicable to project. Also delete any other item or paragraph not applicable in the section and renumber the paragraphs.
3. References to pressures in this Section are gage pressure unless otherwise noted.

DESIGNER NOTES:

1. This specification includes insulation for ductwork installed within buildings and piping and hydronic equipment for ground source heat pump systems. The listed insulation thicknesses are consistent with those required by ASHRAE 90.1 for the most demanding climatic location in the continental United States.
2. Coordinate VA standard details with this specification Section and show details on H drawings as applicable.

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Field applied insulation for thermal efficiency and condensation control for HVAC piping, ductwork, and equipment.
- B. A complete listing of common acronyms and abbreviations are included in Section 23 05 11, COMMON WORK RESULTS FOR HVAC.
- C. Definitions
 1. ASJ: All service jacket, white finish facing or jacket.
 2. Air conditioned space: Space having air temperature and/or humidity controlled by mechanical equipment.
 3. Cold: Equipment, ductwork, or piping handling media at design temperature of 15 degrees C (60 degrees F) or below.
 4. Concealed: Ductwork and piping above ceilings and in chases and pipe spaces.
 5. Exposed: Piping, ductwork, and equipment exposed to view in finished areas including mechanical and electrical equipment rooms or exposed to outdoor weather. Attics and crawl spaces where air handling units are located are considered to be mechanical rooms. Shafts, chases unfinished attics, crawl spaces, and pipe basements are not considered finished areas.

6. FSK: Foil-scrim-kraft facing.
7. Hot: HVAC Ductwork handling air at design temperature above 15 degrees C (60 degrees F); HVAC equipment or piping handling media above 40.5 degrees C (105 degrees F)
8. Density: kg/m³ - kilograms per cubic meter (pcf - pounds per cubic foot).
9. Perm: Metric measure of water vapor transmission in units of 1 grain of water vapor per hour, per square meter, per millimeter of mercury. US measure of water vapor transmission in units of 1 grain of water vapor per hour, per square foot, per inch of mercury.
10. Runouts: Branch pipe connections up to 25 mm (1 inch) nominal size to fan coil units or reheat coils for terminal units.
11. Thermal conductance: Heat flow rate through materials.
 - a. Flat surface: Watt per square meter (BTU per hour per square foot).
 - b. Pipe or Cylinder: Watt per square meter (BTU per hour per linear foot).
12. Thermal Conductivity (k): Watt per meter, per degree C (BTU per inch thickness, per hour, per square foot, per degree F temperature difference).
13. PVDC: Polyvinylidene chloride vapor retarder jacketing, white.

1.2 RELATED WORK

SPEC WRITER NOTE: Retain one of two paragraphs below.

- A. //Section 01 00 01, GENERAL REQUIREMENTS (Major NCA Projects).//
- B. //Section 01 00 02, GENERAL REQUIREMENTS (Minor NCA Projects).//
- C. Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.
- D. Section 01 42 19, REFERENCE STANDARDS.
- E. Section 01 81 13, SUSTAINABLE DESIGN REQUIREMENTS.
- F. //Section 01 91 00, GENERAL COMMISSIONING REQUIREMENTS.//
- G. Section 07 84 00, FIRESTOPPING: Mineral fiber and bond breaker behind sealant.
- H. Section 23 05 11, COMMON WORK RESULTS FOR HVAC: General mechanical requirements and items which are common to more than one section of Division 23.
- I. //Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS.//
- J. Section 23 21 13, HYDRONIC PIPING

K. Section 23 23 00, REFRIGERANT PIPING: Requirements for refrigerant piping and fittings.

L. Section 23 31 00, HVAC DUCTS AND CASINGS: Ductwork and fittings.

1.3 APPLICABLE PUBLICATIONS

SPEC WRITER NOTE: Make material requirements agree with requirements specified in the referenced Applicable Publications. Verify and update the publication list to that which applies to the project, unless the reference applies to all mechanical systems. Publications that apply to all mechanical systems may not be specifically referenced in the body of the specification, but, shall form a part of this specification.

A. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only.

B. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE):
90.1-2013.....Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings

C. American Society for Testing and Materials (ASTM):
A240/A240M-2015b.....Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

B209-2014.....Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

C411-2011.....Standard test Method for Hot-Surface Performance of High-Temperature Thermal Insulation

C449-2007 (R2013).....Standard Specification for Mineral Fiber Hydraulic-Setting Thermal Insulating and Finishing Cement

C518-2015.....Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

C534/C534M-2014.....Standard Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form

- C547-2015.....Standard Specification for Mineral Fiber Pipe Insulation
- C553-2013.....Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
- C591-2015.....Standard Specification for Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation
- C612-2014.....Standard Specification for Mineral Fiber Block and Board Thermal Insulation
- C795-2008 (R2013).....Standard Specification for Thermal Insulation for Use in Contact with Austenitic Stainless Steel
- C871-2011e1.....Standard Test Methods for Chemical Analysis of Thermal Insulation Materials for Leachable Chloride, Fluoride, Silicate, and Sodium Ions
- C921-2010 (R2015).....Standard Practice for Determining the Properties of Jacketing Materials for Thermal Insulation
- C1136-2012.....Standard Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation
- C1290-2011.....Standard Specification for Flexible Fibrous Glass Blanket Insulation Used to Externally Insulate HVAC Ducts
- C1393-2014.....Standard Specification for Perpendicularly Oriented Mineral Fiber Roll and Sheet Thermal Insulation for Pipes and Tanks
- D1644-2001 (R2012).....Standard Test Methods for Nonvolatile Content of Varnishes
- D1668/D1668M-1997a (R2014)e1 Standard Specification for Glass Fabrics (Woven and Treated) for Roofing and Waterproofing
- D1784-2011.....Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
- E84-2015b.....Standard Test Method for Surface Burning Characteristics of Building Materials

- E96/E96M-2015.....Standard Test Methods for Water Vapor
Transmission of Materials
- F1249-2013.....Standard Test Method for Water Vapor
Transmission Rate Through Plastic Film and
Sheeting Using a Modulated Infrared Sensor
- D. Federal Specifications (Fed. Spec.):
- L-P-535E-2012.....Plastic Sheet (Sheeting): Plastic Strip; Poly
(Vinyl Chloride) and Poly (Vinyl Chloride -
Vinyl Acetate), Rigid
- E. Military Specifications (Mil. Spec.):
- MIL-A-24179A (1)-1987...Adhesive, Flexible Unicellular-Plastic Thermal
Insulation
- MIL-A-3316C (2)-1990....Adhesives, Fire-Resistant, Thermal Insulation
- MIL-C-20079H-87.....Cloth, Glass; Tape, Textile Glass; and Thread,
Glass and Wire-Reinforced Glass
- MIL-PRF-19565C (1)-1988.Coating Compounds, Thermal Insulation, Fire,
and Water-Resistant, Vapor-Barrier
- F. National Fire Protection Association (NFPA):
- 90A-2015.....Standard for the Installation of Air-
Conditioning and Ventilating Systems
- 90B-2015.....Standard for the Installation of Warm Air
Heating and Air-Conditioning Systems
- 251-2006.....Standard Methods of Tests of Fire Resistance of
Building Construction Materials
- 255-2006.....Standard Method of Test of Surface Burning
Characteristics of Building Materials
- 262-2015.....Standard Method of Test for Flame Travel and
Smoke of Wires and Cables for Use in Air-
Handling Spaces
- G. Underwriters Laboratories, Inc. (UL):
- 181-2013.....Standard for Factory-Made Air Ducts and Air
Connectors
- 181A-2013.....Standard for Closure Systems for User with
Rigid Air Ducts
- 181B-2013.....Standard for Closure Systems for Use with
Flexible Air Ducts and Air Connectors
- 723-2008 (R2013).....Standard for Test for Surface Burning
Characteristics of Building Materials

1820-2004 (R2013).....Standard for Fire Test of Pneumatic Tubing for
Flame and Smoke Characteristics

1.4 SUBMITTALS

- A. Submittals, including number of required copies, shall be submitted in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.
- B. Information and material submitted under this section shall be marked "SUBMITTED UNDER SECTION 23 07 11, HVAC INSULATION", with applicable paragraph identification.
- C. Manufacturer's Literature and Data including: Full item description and optional features and accessories. Include dimensions, weights, materials, applications, standard compliance, model numbers, size, and capacity.
- D. Shop Drawings:
 - 1. All information shall be included as to be able to clearly determine compliance with contract documents, ASTM standards, and federal and military specifications. For each type of product indicated, include thermal conductivity, water-vapor permeance thickness, and jackets (both factory-applied and field-applied if any).
 - a. Insulation materials: Specify each type used and state surface burning and smoke developed characteristics.
 - b. Insulation facings and jackets: Each type used. White finish shall be furnished for exposed ductwork, casings, and equipment.
 - c. Insulation accessory materials: Each type used.
 - d. Manufacturer's installation and fitting fabrication instructions for flexible unicellular insulation.
 - e. Make reference to applicable specification paragraph numbers for coordination.
- E. //Completed System Readiness Checklist provided by the Commissioning Agent and completed by the contractor, signed by a qualified technician and dated on the date of completion, in accordance with the requirements of Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS.//

1.5 QUALITY ASSURANCE

- A. Refer to paragraph QUALITY ASSURANCE, in Section 23 05 11, COMMON WORK RESULTS FOR HVAC.

B. Criteria:

1. Comply with NFPA 90A.

- a. For installation indoors pipe insulation and coverings, duct coverings, duct linings, vapor retarder facings, adhesives, fasteners, tapes, and supplementary materials added to air ducts, plenums, panels, and duct silencers used in duct systems shall have, in the form in which they are used, a maximum flame spread index of 25 without evidence of continued progressive combustion and a maximum smoke developed index of 50 when tested in accordance with NFPA 255 or ASTM E84.
- b. For installations outdoors the maximum flame spread index is 75 and the maximum smoke developed index is 150 for insulation and covering materials that do not penetrate a wall or roof, and do not create an exposure hazard.
- c. Where products are to be applied with adhesives, they shall be tested with such adhesives applied, or the adhesives used shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when in the final dry state.
- d. Closure systems for use with rigid and flexible air ducts tested in accordance with UL 181, Standard for Safety Factory-Made Air Ducts and Air Connectors, shall have been tested, listed, and used in accordance with the conditions of their listings in accordance with one of the following:
 - 1) UL 181A, Standard for Safety Closure Systems for Use with Rigid Air Ducts and Air Connectors
 - 2) UL 181B, Standard for Safety Closure Systems for Use with Flexible Air Ducts and Air Connectors
- e. Air duct, panel, and plenum coverings and linings, and pipe insulation and coverings shall not flame, glow, smolder, or smoke when tested in accordance with a similar test for pipe covering, ASTM C411 at the temperature to which they are exposed in service.
- f. In no case shall the test temperature be below 121 degrees C (250 degrees F).
- g. Air duct coverings shall not extend through walls or floors that are required to be fire stopped or required to have a fire resistance rating.

- h. Air duct linings shall be interrupted at fire dampers to prevent interference with the operation of devices.
 - i. Air duct coverings shall not be installed so as to conceal or prevent the use of any service opening.
 - j. Materials exposed to the airflow shall be noncombustible or limited combustible and have a maximum smoke developed index of 50 or comply with the following.
 - k. Electrical wires and cables and optical fiber cables shall be listed as noncombustible or limited combustible and have a maximum smoke developed index of 50 or shall be listed as having a maximum peak optical density of 0.5 or less, an average optical density of 0.15 or less, and a maximum flame spread distance of 1.5 m (5 feet) or less when tested in accordance with NFPA 262, Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces.
 - l. Pneumatic tubing for control systems shall be listed as having a maximum peak optical density of 0.5 or less, an average optical density of 0.15 or less, and a maximum flame spread distance of 1.5 m (5 feet) or less when tested in accordance with UL 1820, Standard for Safety Fire Test of Pneumatic Tubing for Flame and Smoke Characteristics.
 - m. Supplementary materials for air distribution systems shall comply with the provisions of air distribution materials.
 - n. Where air ducts pass through walls, floors, or partitions that are required to have a fire resistance rating and where fire dampers are not required, the opening in the construction around the air duct shall be as follows:
 - 1) Not exceeding a 25 mm (1 inch) average clearance on all sides
 - 2) Filled solid with an approved material capable of preventing the passage of flame and hot gases as specified in NFPA 251.
2. Test methods: ASTM E84, UL 723, or NFPA 255.
3. Specified k-values are in accordance with ASTM test methods including ASTM C518 and ASTM C411 at 24 degrees C (75 degrees F) mean temperature unless stated otherwise. Where optional thermal insulation material is used, select thickness to provide thermal conductance no greater than that for the specified material. For pipe, use insulation manufacturer's published heat flow tables. For domestic hot water supply and return, run out insulation and

- condensation control insulation, no thickness adjustment need be made.
4. All materials shall be compatible and suitable for service temperature, and shall not contribute to corrosion or otherwise attack surface to which applied in either the wet or dry state.
- C. Every package or standard container of insulation or accessories delivered to the job site for use must have a manufacturer's stamp or label giving the name of the manufacturer and description of the material.

1.6 STORAGE AND HANDLING OF MATERIAL

- A. Store materials in clean and dry environment; pipe covering jackets shall be clean and unmarred. Place adhesives in original containers. Maintain ambient temperatures and conditions as required by printed instructions of manufacturers of adhesives, mastics, and finishing cements.
- B. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

PART 2 - PRODUCTS

SPEC WRITE NOTE: Make material requirements agree with applicable requirements specified in the referenced Applicable Publications. Update and specify only that which applies to the project.

2.1 INSULATION MATERIALS

- A. Do not use materials containing asbestos, lead, mercury, or mercury compounds.
- B. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C871.
- C. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C795.
- D. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

2.2 MINERAL FIBER BOARD OR BLOCK, BLANKET, AND PREFORMED PIPE INSULATION

- A. ASTM C612, Type 1A or Type 1B. Board or block insulation with mineral or glass fibers bonded with thermosetting resin. Density 48 kg/m³ (3.0 pcf), labeled thickness thermal conductivity (k-value) 0.23 Btu x

inches / Hr x sq. ft. x deg. F (0.042 W/m x K) or less at 24 degrees C (75 degrees F), and maximum temperature 93 degrees C (200 degrees F) or greater.

- B. ASTM C553, Type II, or ASTM C1290, Type III with factory Foil-Scrim-Kraft jacket. Flexible blanket insulation with mineral or glass fibers bonded with thermosetting resin. Density 12 kg/m³ (0.75 pcf), labeled thickness thermal conductivity (k-value) 0.29 Btu x inches / Hr x sq. ft. x deg. F (0.033 W/m x K) or less at 24 degrees C (75 degrees F), and maximum temperature 93 degrees C (200 degrees F) or greater.
- C. ASTM C547, Type I, Grade A, with factory-applied ASJ jacket. Preformed pipe insulation with glass fibers bonded with a thermosetting resin. Jacket complying with ASTM C1136, Type I with polyvinyl chloride pre-molded fitting covers. Labeled thickness thermal conductivity (k-value) 0.23 Btu x inches / Hr x sq. ft. x deg. F (0.034 W/m x K) or less at 24 degrees C (75 degrees F), and minimum temperature minus 18 degrees C (0 degrees F) or less, and maximum temperature 454 degrees C (850 degrees F) or greater.

2.3 MINERAL WOOL OR REFRACTORY FIBER FOR INSULATION

- A. Comply with ASTM C612 for board and block insulation, Type 1A-III, maximum temperature 454 degrees C (850 degrees F).
- B. Comply with ASTM C1393 for pipe insulation.

2.4 POLYISOCYANURATE CLOSED-CELL RIGID PREFORMED PIPE AND EQUIPMENT INSULATION

- A. ASTM C591, Grade 2, Type I. Preformed pipe insulation. Thermal conductivity (k-value) 0.19 Btu x inches / Hr x sq. ft. x deg. F (0.027 W/m x K) or less at 24 degrees C (75 degrees F), and minimum temperature minus 18 degrees C (0 degrees F) or less, and maximum temperature 149 degrees C (300 degrees F) or greater. With factory applied PVDC or all service jacket vapor retarder with polyvinyl chloride pre-molded fitting covers.
- B. Equipment insulation, ASTM C591, Type IV. Thermal conductivity (k-value) 0.19 Btu x inches / Hr x sq. ft. x deg. F (0.027 W/m x K) or less at 24 degrees C (75 degrees F), and minimum temperature minus 18 degrees C (0 degrees F) or less, and maximum temperature 149 degrees C (300 degrees F) or greater. With PVDC or all service jacket vapor retarder jacket.

2.5 FLEXIBLE ELASTOMERIC CELLULAR THERMAL PREFORMED PIPE AND EQUIPMENT INSULATION

- A. ASTM C534/C534M, Grade I for tube and sheet materials. Thermal conductivity (k-value) 0.21 Btu x inches / Hr x sq. ft. x deg. F (0.030 W/m x K) or less at 24 degrees C (75 degrees F), and minimum temperature minus 18 degrees C (0 degrees F) or less, and maximum temperature 104 degrees C (220 degrees F) or greater. No jacket required.

2.6 INSULATION FACINGS AND JACKETS

- A. Vapor retarder, higher strength with low water permeance = 0.02 or less perm rating. Beach puncture 50 units for insulation facing on exposed ductwork, casings and equipment, and for pipe insulation jackets. Facings and jackets shall be all service type (ASJ) or PVDC Vapor Retarder jacketing.
- B. ASJ jacket shall be white kraft bonded to 0.025 mm (1 mil) thick aluminum foil, fiberglass reinforced. Comply with ASTM C1136, Type I. Beach puncture 50 Beach Units (1.5 Joules) minimum. Suitable for painting without sizing. Jackets shall have minimum 40 mm (1-1/2 inch) lap on longitudinal joints and minimum 100 mm (4 inch) butt strip on end joints. Butt strip material shall be same as the jacket. Lap and butt strips shall be self-sealing type with factory-applied pressure sensitive adhesive.
- C. Vapor retarder medium strength with low water vapor permeance of 0.132 metric perm (0.02 or less perm rating). Beach puncture 25 units: Foil-Scrim-Kraft (FSK) or PVDC vapor retarder jacketing type for concealed ductwork and equipment.
- D. Glass Cloth Jackets: Presized, minimum 0.18 kg per square meter (7.8 ounces per square yard), 2070 kPa (300 psi) bursting strength with integral vapor retarder where required or specified. Weather proof if utilized for outside service.
- E. Factory composite materials may be used provided that they have been tested and certified by the manufacturer.
- F. Pipe fitting insulation covering (jackets): Fitting covering shall be premolded to match shape of fitting and shall be polyvinyl chloride (PVC) conforming to Fed Spec L-P-565E, composition A, Type II Grade GU, and Type III, minimum thickness 0.7 mm (0.03 inches). Provide color matching vapor retarder pressure sensitive tape.

- G. Aluminum jacket piping systems and circular breeching and stacks: ASTM B209, 3003 alloy, H-14 temper, 0.6 mm (0.024 inch) minimum thickness with locking longitudinal joints. Jackets for elbows, tees and other fittings shall be factory-fabricated to match shape of fitting and of 0.6 mm (0.024) inch minimum thickness aluminum. Fittings shall be of same construction as straight run jackets but need not be of the same alloy. Factory-fabricated stainless steel bands shall be installed on all circumferential joints. Bands shall be 20 mm (3/4 inch) wide on 450 mm (18 inch) centers. System shall be weatherproof if utilized for outside service.
- H. Aluminum jacket rectangular breeching: ASTM B209, 3003 alloy, H-14 temper, 0.5 mm (0.020 inches) thick with 32 mm (1-1/4 inch) corrugations or 0.8 mm (0.032 inches) thick with no corrugations. System shall be weatherproof if used for outside service.

2.7 PIPE COVERING PROTECTION SADDLES

- A. Cold pipe support: Premolded pipe insulation 180 degrees (half-shells) on bottom half of pipe at supports. Material shall be cellular glass or high density polyisocyanurate insulation of the same thickness as adjacent insulation. Density of polyisocyanurate insulation shall be a minimum of 48 kg/m³ (3.0 pcf).

Nominal Pipe Size and Accessories Material (Insert Blocks)	
Nominal Pipe Size mm (inches)	Insert Blocks mm (inches)
Up through 125 (5)	150 (6) long

- B. Warm or hot pipe supports: Premolded pipe insulation (180 degree half-shells) on bottom half of pipe at supports. Material shall be high density polyisocyanurate for temperatures up to 149 degrees C (300 degrees F) cellular glass. Insulation at supports shall have same thickness as adjacent insulation. Density of polyisocyanurate insulation shall be a minimum of 48 kg/m³ (3.0 pcf).

2.8 ADHESIVE, MASTIC, CEMENT

- A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.
- B. Mil. Spec. MIL-A-3316C, Class 1: Jacket and lap adhesive and protective finish coating for insulation.
- C. Mil. Spec. MIL-A-3316C, Class 2: Adhesive for laps and for adhering insulation to metal surfaces.

- D. Mil. Spec. MIL-A-24179A, Type II Class 1: Adhesive for installing flexible unicellular insulation and for laps and general use.
- E. Mil. Spec. MIL-PRF-19565C, Type I: Protective finish for outdoor use.
- F. Mil. Spec. MIL-PRF-19565C, Type I or Type II: Vapor barrier compound for indoor use.
- G. ASTM C449: Mineral fiber hydraulic-setting thermal insulating and finishing cement.
- H. Other: Insulation manufacturers' published recommendations.

2.9 MASTICS

- A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.
- B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below ambient services.
 - 1. Water-Vapor Permeance: ASTM E96/E96M, Procedure B, 0.013 perm (0.009 metric perm) at 43 mil (1.09 mm) dry film thickness.
 - 2. Service Temperature Range: Minus 29 to plus 82 degrees C (Minus 20 to plus 180 degrees F).
 - 3. Solids Content: ASTM D1644, 58 percent by volume and 70 percent by weight.
 - 4. Color: White.
- C. Vapor-Barrier Mastic: Solvent based; suitable for indoor use on below ambient services.
 - 1. Water-Vapor Permeance: ASTM F1249, 0.05 perm (0.03 metric perm) at 35 mil (0.9 mm) dry film thickness.
 - 2. Service Temperature Range: Minus 18 to plus 82 degrees C (0 to 180 degrees F).
 - 3. Solids Content: ASTM D1644, 44 percent by volume and 62 percent by weight.
 - 4. Color: White.
- D. Vapor-Barrier Mastic: Solvent based; suitable for outdoor use on below ambient services.
 - 1. Water-Vapor Permeance: ASTM F1249, 0.05 perm (0.033 metric perm) at 30 mil (0.8 mm) dry film thickness.
 - 2. Service Temperature Range: Minus 46 to plus 104 degrees C (Minus 50 to plus 220 degrees F).
 - 3. Solids Content: ASTM D1644, 33 percent by volume and 46 percent by weight.
 - 4. Color: White.

- E. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.
1. Water-Vapor Permeance: ASTM F1249, 1.8 perms (1.2 metric perms) at 1.6 mm (0.0625 inch) dry film thickness.
 2. Service Temperature Range: Minus 29 to plus 82 degrees C (Minus 20 to plus 180 degrees F).
 3. Solids Content: 60 percent by volume and 66 percent by weight.
 4. Color: White.

2.10 SEALANTS

- A. FSK and Metal Jacket Flashing Sealants:
1. Materials shall be compatible with insulation materials, jackets, and substrates.
 2. Fire- and water-resistant, flexible, elastomeric sealant.
 3. Service Temperature Range: Minus 40 to plus 121 degrees C (Minus 40 to plus 250 degrees F).
 4. Color: Aluminum.
- B. ASJ Flashing Sealants, and Vinyl and PVC Jacket Flashing Sealants:
1. Materials shall be compatible with insulation materials, jackets, and substrates.
 2. Fire- and water-resistant, flexible, elastomeric sealant.
 3. Service Temperature Range: Minus 40 to plus 121 degrees C (Minus 40 to plus 250 degrees F).
 4. Color: White.

2.11 FACTORY-APPLIED JACKETS

- A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C1136, Type I.
 2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C1136, Type I.
 3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C1136, Type II.
 4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C1136, Type II.

5. Vinyl Jacket: White vinyl with a permeance of 1.3 perms (0.86 metric perm) when tested according to ASTM E96/E96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.12 FIELD-APPLIED JACKETS

- A. Field-applied jackets shall comply with ASTM C921, Type I, unless otherwise indicated.
- B. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.
- C. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.
1. Adhesive: As recommended by jacket material manufacturer.
 2. Color: //White// //Color-code jackets based on system. Color as selected by Architect//.
- D. Metal Jacket:
1. Aluminum Jacket: Comply with ASTM B209, Alloy 3003, 3005, 3105, or 5005, Temper H-14.
 - a. //Sheet and roll stock ready for shop or field sizing// //Factory cut and rolled to size//.
 - b. Finish and thickness are indicated in field-applied jacket schedules.
 - c. Moisture Barrier for Indoor Applications: //0.025 mm (1 mil) thick, heat-bonded polyethylene and kraft paper// //0.075 mm (3 mil) thick, heat-bonded polyethylene and kraft paper// //0.063 mm (2.5 mil) thick polysurlyn//.
 - d. Moisture Barrier for Outdoor Applications: //0.075 mm (3 mil) thick, heat-bonded polyethylene and kraft paper// //0.063 mm (2.5 mil) thick polysurlyn//.
 2. Stainless-Steel Jacket: ASTM A240/A240M.
 - a. //Sheet and roll stock ready for shop or field sizing// //Factory cut and rolled to size//.
 - b. Material, finish, and thickness are indicated in field-applied jacket schedules.
 - c. Moisture Barrier for Indoor Applications: //0.025 mm (1 mil) thick, heat-bonded polyethylene and kraft paper// //0.075 mm (3 mil) thick, heat-bonded polyethylene and kraft paper// //0.063 mm (2.5 mil) thick polysurlyn//.

- d. Moisture Barrier for Outdoor Applications: //0.075 mm (3 mil) thick, heat-bonded polyethylene and kraft paper// //0.063 mm (2.5 mil) thick polysurlyn//.
- E. Self-Adhesive Outdoor Jacket: 1.5 mm (60 mil) thick, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a crosslaminated polyethylene film covered with //white// //stucco-embossed// aluminum-foil facing.

2.13 TAPES

- A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C1136.
 - 1. Width: 75 mm (3 inches).
 - 2. Thickness: 0.29 mm (11.5 mils).
 - 3. Adhesion: 1.0 N/mm (90 ounces force/inch) in width.
 - 4. Elongation: 2 percent.
 - 5. Tensile Strength: 7.2 N/mm (40 lbf/inch) in width.
 - 6. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.
- B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C1136.
 - 1. Width: 75 mm (3 inches).
 - 2. Thickness: 0.16 mm (6.5 mils).
 - 3. Adhesion: 1.0 N/mm (90 ounces force/inch) in width.
 - 4. Elongation: 2 percent.
 - 5. Tensile Strength: 7.2 N/mm (40 lbf/inch) in width.
 - 6. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.
- C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.
 - 1. Width: 50 mm (2 inches).
 - 2. Thickness: 0.15 mm (6 mils).
 - 3. Adhesion: 0.7 N/mm (64 ounces force/inch) in width.
 - 4. Elongation: 500 percent.
 - 5. Tensile Strength: 3.3 N/mm (18 lbf/inch) in width.
- D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.
 - 1. Width: 50 mm (2 inches).
 - 2. Thickness: 0.093 mm (3.7 mils).
 - 3. Adhesion: 1.1 N/mm (100 ounces force/inch) in width.
 - 4. Elongation: 5 percent.
 - 5. Tensile Strength: 6.2 N/mm (34 lbf/inch) in width.

2.14 MECHANICAL FASTENERS

- A. Pins, anchors: Welded pins, or metal or nylon anchors with tin-coated or fiber washer, or clips. Pin diameter shall be as recommended by the insulation manufacturer.
- B. Staples: Outward clinching monel or stainless steel.
- C. Wire: 1.3 mm (18 gage) thick soft annealed galvanized or 1.9 mm (14 gage) copper clad steel or nickel copper alloy.
- D. Bands: 20 mm (3/4 inch) nominal width, brass, galvanized steel, aluminum or stainless steel.

2.15 REINFORCEMENT AND FINISHES

- A. Glass fabric, open weave: ASTM D1668/D1668M, Type III (resin treated) and Type I (asphalt treated).
- B. Glass fiber fitting tape: Mil. Spec MIL-C-20079H, Type II, Class 1.
- C. Tape for Flexible Elastomeric Cellular Thermal Insulation: As recommended by the insulation manufacturer.
- D. Corner angles: 50 mm by 50 mm (2 inch by 2 inch), 0.55 mm (26 gage) thick galvanized steel; or, 25 mm by 25 mm (1 inch by 1 inch), 0.47 mm (28 gage) thick aluminum angle adhered to 50 mm by 50 mm (2 inch by 2 inch) Kraft paper, or PVC Corner Angles: //30 mils (0.76 mm)// // // thick, minimum 25 mm by 25 mm (1 inch by 1 inch), PVC according to ASTM D1784, Class 16354-C. White or color-coded to match adjacent surface, or Stainless-Steel Corner Angles: //0.6 mm (0.024 inch)// // // thick, minimum 25 mm by 25 mm (1 inch by 1 inch)), stainless steel according to ASTM A240/A240M, //Type 304// //or// //Type 316//.
- E. PVC fitting cover: Fed. Spec L-P-535E, Composition A, 11-86 Type II, Grade GU, with Form B Mineral Fiber insert, for media temperature 4 degrees C (40 degrees F) to 121 degrees C (250 degrees F). Below 4 degrees C (40 degrees F) and above 121 degrees C (250 degrees F). Provide double layer insert. Provide color matching vapor barrier pressure sensitive tape.

2.16 FIRESTOPPING MATERIAL

- A. Other than pipe and duct insulation, refer to Section 07 84 00, FIRESTOPPING.

2.17 FLAME AND SMOKE

- A. Unless shown otherwise all assembled systems shall meet flame spread 25 and smoke developed 50 rating as developed under ASTM, NFPA and UL standards and specifications. See paragraph QUALITY ASSURANCE.

PART 3 - EXECUTION**3.1 GENERAL REQUIREMENTS**

- A. If an installation is unsatisfactory to the COR, the Contractor shall correct the installation at no additional cost or time to the Government.
- B. Required pressure tests of duct and piping joints and connections shall be completed and the work approved by the Contracting Officer's Representative (COR) for application of insulation. Surface shall be clean and dry with all foreign materials, such as dirt, oil, loose scale and rust removed.
- C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.
- D. Install insulation with longitudinal seams at top and bottom of horizontal runs.
- E. Install multiple layers of insulation with longitudinal and end seams staggered.
- F. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.
- G. Keep insulation materials dry during application and finishing.
- H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- I. Install insulation with least number of joints practical.
- J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
 - 1. Install insulation continuously through hangers and around anchor attachments.
 - 2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
 - 3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.
- K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- L. Install insulation with factory-applied jackets as follows:
 1. Draw jacket tight and smooth.
 2. Cover circumferential joints with 75 mm (3 inch) wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 100 mm (4 inches)) on center.
 3. Overlap jacket longitudinal seams at least 40 mm (1-1/2 inches). Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at //50 mm (2 inches)// //100 mm (4 inches)// on center.
 - a. For below ambient services, apply vapor-barrier mastic over staples.
 4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
 5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct flanges and fittings.
- M. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
- N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
- O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 100 mm (4 inches) beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.
- P. For above-ambient services, do not install insulation to the following:
 1. Vibration-control devices.
 2. Testing agency labels and stamps.
 3. Nameplates and data plates.
 4. Manholes.
 5. Handholes.
 6. Cleanouts.
- Q. Except for specific exceptions, insulate entire specified equipment, piping (pipe, fittings, valves, accessories), and duct systems.

Insulate each pipe and duct individually. Do not use scrap pieces of insulation where a full length section will fit.

- R. Insulation materials shall be installed in a first class manner with smooth and even surfaces, with jackets and facings drawn tight and smoothly cemented down at all laps. Insulation shall be continuous through all sleeves and openings, except at fire dampers and duct heaters in accordance with NFPA 90A. Vapor retarders shall be continuous and uninterrupted throughout systems with operating temperature 15 degrees C (60 degrees F) and below. Lap and seal vapor barrier over ends and exposed edges of insulation. Anchors, supports and other metal projections through insulation on cold surfaces shall be insulated and vapor sealed for a minimum length of 150 mm (6 inches).
- S. Install vapor stops at all insulation terminations on either side of valves, pumps and equipment and particularly in straight lengths of pipe insulation.
- T. Construct insulation on parts of equipment such as heat exchangers that must be opened periodically for maintenance or repair, so insulation can be removed and replaced without damage. Install insulation with bolted 1 mm (20 gage) thick galvanized steel or aluminum covers as complete units, or in sections, with all necessary supports, and split to coincide with flange/split of the equipment.
- U. Insulation on hot piping and equipment shall be terminated square at items not to be insulated, access openings and nameplates. Cover all exposed raw insulation with white sealer or jacket material.
- V. Protect all insulations outside of buildings with aluminum jacket using lock joint or other approved system for a continuous weather tight system. Access doors and other items requiring maintenance or access shall be removable and sealable.
- W. HVAC work not to be insulated:
 - 1. Internally insulated ductwork and air handling units.
 - 2. Exhaust air ducts and ventilation exhaust air shafts.

SPEC WRITER NOTE: Edit this list if additional equipment is required, or if certain equipment is insulated for safety reasons.

- 3. Equipment: Expansion tanks and hot water pumps.

4. In hot piping: Unions, flexible connectors, control valves, PRVs, safety valves and discharge vent piping. Insulate piping to within approximately 75 mm (3 inches) of uninsulated items.
- X. Apply insulation materials subject to the manufacturer's recommended temperature limits. Apply adhesives, mastic and coatings at the manufacturer's recommended minimum coverage.
- Y. Elbows, flanges and other fittings shall be insulated with the same material as is used on the pipe straights. The elbow/ fitting insulation shall be field-fabricated, mitered or factory prefabricated to the necessary size and shape to fit on the elbow/ fitting. Use of polyurethane spray-foam to fill a PVC elbow jacket is prohibited on cold applications.
- Z. Firestop Pipe and Duct insulation:
 1. Provide firestopping insulation at fire and smoke barriers through penetrations. Fire stopping insulation shall be UL listed as defines in Section 07 84 00, FIRESTOPPING.
 2. Pipe and duct penetrations requiring fire stop insulation including, but not limited to the following:
 - a. Pipe risers through floors
 - b. Pipe or duct chase walls and floors
 - c. Smoke partitions
 - d. Fire partitions
- AA. Freeze protection of above grade outdoor piping (over heat tracing tape): 20 mm (3/4 inches) thick insulation, for all pipe sizes 75 mm (3 inches) and smaller and 25 mm (1 inch) thick insulation for larger pipes. Provide metal jackets for all pipes.
- BB. Provide metal jackets over insulation as follows:
 1. All piping and ducts exposed to outdoor weather.
 2. Piping exposed in building, within 1800 mm (6 feet) of the floor, that connects to sterilizers, kitchen and laundry equipment. Jackets may be applied with pop rivets. Provide aluminum angle ring escutcheons at wall, ceiling or floor penetrations.
 3. A 50 mm (2 inch) overlap is required at longitudinal and circumferential joints.

3.2 INSULATION INSTALLATION

- A. Mineral Fiber Board:
 1. Faced board: Apply board on pins spaced not more than 300 mm (12 inches) on center each way, and not less than 75 mm (3 inches) from

each edge of board. In addition to pins, apply insulation bonding adhesive to entire underside of horizontal metal surfaces. Butt insulation edges tightly and seal all joints with laps and butt strips. After applying speed clips cut pins off flush and apply vapor seal patches over clips.

2. Plain board:

- a. Insulation shall be scored, beveled or mitered to provide tight joints and be secured to equipment with bands spaced 225 mm (9 inches) on center for irregular surfaces or with pins and clips on flat surfaces. Use corner beads to protect edges of insulation.
- b. For hot equipment: Stretch 25 mm (1 inch) mesh wire, with edges wire laced together, over insulation and finish with insulating and finishing cement applied in one coat, 6 mm (1/4 inch) thick, trowel led to a smooth finish.
- c. For cold equipment: Apply meshed glass fabric in a tack coat 1.5 to 1.7 square meter per liter (60 to 70 square feet per gallon) of vapor mastic and finish with mastic at 0.3 to 0.4 square meter per liter (12 to 16 square feet per gallon) over the entire fabric surface.

SPEC WRITER NOTE: Provide 50 mm (2 inch) duct insulation for supply and 40 mm (1-1/2 inch) for return duct work exposed to severe outdoor conditions.

B. Flexible Mineral Fiber Blanket: Adhere insulation to metal with 100 mm (4 inch) wide strips of insulation bonding adhesive at 200 mm (8 inches) on center all around duct. Additionally secure insulation to bottom of ducts exceeding 600 mm (24 inches) in width with pins welded or adhered on 450 mm (18 inch) centers. Secure washers on pins. Butt insulation edges and seal joints with laps and butt strips. Staples may be used to assist in securing insulation. Seal all vapor retarder penetrations with mastic. Sagging duct insulation will not be acceptable. Install firestop duct insulation where required.

C. Molded Mineral Fiber Pipe and Tubing Covering:

1. Fit insulation to pipe or duct, aligning longitudinal joints. Seal longitudinal joint laps and circumferential butt strips by rubbing hard with a nylon sealing tool to assure a positive seal. Staples may be used to assist in securing insulation. Seal all vapor retarder penetrations on cold piping with a generous application of

- vapor barrier mastic. Provide inserts and install with metal insulation shields at outside pipe supports. Install freeze protection insulation over heating cable.
2. Contractor's options for fitting, flange and valve insulation:
 - a. Insulating and finishing cement for sizes less than 100 mm (4 inches) operating at surface temperature of 16 degrees C (61 degrees F) or more.
 - b. Factory premolded, one piece PVC covers with mineral fiber, (Form B), inserts. Provide two insert layers for pipe temperatures below 4 degrees C (40 degrees F), or above 121 degrees C (250 degrees F). Secure first layer of insulation with twine. Seal seam edges with vapor barrier mastic and secure with fitting tape.
 - c. Factory molded, ASTM C547 or field mitered sections, joined with adhesive or wired in place. For hot piping finish with a smoothing coat of finishing cement. For cold fittings, 15 degrees C (59 degrees F) or less, vapor seal with a layer of glass fitting tape imbedded between two 1.6 mm (1/16 inch) coats of vapor barrier mastic.
 - d. Fitting tape shall extend over the adjacent pipe insulation and overlap on itself at least 50 mm (2 inches).

SPEC WRITER NOTE: Need for insulation for cold water piping depends upon location of Cemetery.

D. Polyisocyanurate Closed-Cell Rigid Insulation:

1. Polyisocyanurate closed-cell rigid insulation (PIR) may be provided for piping, equipment and ductwork for temperature up to 149 degree C (300 degree F) provided insulation thickness requirement does not exceed 40 mm (1-1/2 inches).
2. Install insulation, vapor retarder and jacketing per manufacturer's recommendations. Particular attention should be paid to recommendations for joint staggering, adhesive application, external hanger design, expansion/contraction joint design and spacing and vapor retarder integrity.
3. Install insulation with all joints tightly butted (except expansion joints in hot applications).

4. If insulation thickness exceeds 65 mm (2-1/2 inches), install as a double layer system with longitudinal (lap) and butt joint staggering as recommended by manufacturer.
 5. For cold applications, vapor retarder shall be installed in a continuous manner. No staples, rivets, screws or any other attachment device capable of penetrating the vapor retarder shall be used to attach the vapor retarder or jacketing. No wire ties capable of penetrating the vapor retarder shall be used to hold the insulation in place. Banding shall be used to attach PVC or metal jacketing.
 6. Elbows, flanges and other fittings shall be insulated with the same material as is used on the pipe straights. The elbow/ fitting insulation shall be field-fabricated, mitered or factory prefabricated to the necessary size and shape to fit on the elbow/ fitting. Use of polyurethane spray-foam to fill PVC elbow jacket is prohibited on cold applications.
 7. For cold applications, the vapor retarder on elbows/fittings shall be either mastic-fabric-mastic or 0.05 mm (2 mils) thick PVDC vapor retarder adhesive tape.
 8. All PVC and metal jacketing shall be installed so as to naturally shed water. Joints shall point down and shall be sealed with either adhesive or caulking (except for periodic slip joints).
 9. Note the NFPA 90A burning characteristic requirements of 25/50. Refer to paragraph GENERAL REQUIREMENTS for items not to be insulated.
 10. HVAC Condensation Control Insulation: Minimum 20 mm (3/4 inch) thick for all pipe sizes. Cooling coil condensation piping to waste piping fixture or drain inlet. Omit insulation on plastic piping in mechanical rooms.
- E. Flexible Elastomeric Cellular Thermal Insulation:
1. Apply insulation and fabricate fittings in accordance with the manufacturer's installation instructions and finish with two coats of weather resistant finish as recommended by the insulation manufacturer.
 2. Pipe and tubing insulation:
 - a. Use proper size material. Do not stretch or strain insulation.
 - b. To avoid undue compression of insulation, provide cork stoppers or wood inserts at supports as recommended by the insulation

manufacturer. Insulation shields are specified under Section 23 05 11, COMMON WORK RESULTS FOR HVAC.

- c. Where possible, slip insulation over the pipe or tubing prior to connection, and seal the butt joints with adhesive. Where the slip-on technique is not possible, slit the insulation and apply it to the pipe sealing the seam and joints with contact adhesive. Optional tape sealing, as recommended by the manufacturer, may be employed. Make changes from mineral fiber insulation in a straight run of pipe, not at a fitting. Seal joint with tape.
- 3. Apply sheet insulation to flat or large curved surfaces with 100 percent adhesive coverage. For fittings and large pipe, apply adhesive to seams only.

3.3 INSULATION APPLICATION - DUCTWORK

A. Supply Air Ductwork transporting air that may sometimes may be colder than surrounding ambient or room temperature.

- 1. Concealed in conditioned locations:
 - a. Round ductwork: //1-1/2-inch thick mineral fiber blanket with factory applied FSK// or //1-inch thick elastomeric//.
 - b. Rectangular ductwork: //1-inch thick mineral fiber board with factory applied FSK// or //1-1/2-inch thick mineral fiber blanket with factory applied FSK// or //1-inch thick polyisocyanurate with factory applied ASJ or PVDC// or //1-inch thick elastomeric//.
- 2. Exposed in conditioned locations:
 - a. Round ductwork: //1-1/2-inch thick mineral fiber blanket with factory applied FSK// or //1-inch thick elastomeric//.
 - b. Rectangular ductwork: //1-inch thick mineral fiber board with factory applied FSK// or //1-1/2-inch thick mineral fiber blanket with factory applied FSK// or //1-inch thick polyisocyanurate with factory applied ASJ or PVDC// or //1-inch thick elastomeric//.
- 3. Concealed in unconditioned locations:
 - a. Round ductwork: //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick elastomeric//.
 - b. Rectangular ductwork: //2-inch thick mineral fiber board with factory applied FSK// or //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick polyisocyanurate with factory applied ASJ or PVDC// or //1-1/2-inch thick elastomeric//.

4. Exposed in unconditioned locations:
 - a. Round ductwork: //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick elastomeric//.
 - b. Rectangular ductwork: //2-inch thick mineral fiber board with factory applied FSK// or //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick polyisocyanurate with factory applied ASJ or PVDC// or //1-1/2-inch thick elastomeric//.
- B. Outdoor Air Ductwork transporting air that has not been heated or cooled.
 1. Concealed in conditioned locations:
 - a. Round ductwork: //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick elastomeric//.
 - b. Rectangular ductwork: //2-inch thick mineral fiber board with factory applied FSK// or //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick polyisocyanurate with factory applied ASJ or PVDC// or //1-1/2-inch thick elastomeric//.
 2. Exposed in conditioned locations:
 - a. Round ductwork: //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick elastomeric//.
 - b. Rectangular ductwork: //2-inch thick mineral fiber board with factory applied FSK// or //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick polyisocyanurate with factory applied ASJ or PVDC// or //1-1/2-inch thick elastomeric//.
 3. Concealed in unconditioned locations:
 - a. Round ductwork: None
 - b. Rectangular ductwork: None
 4. Exposed in unconditioned locations:
 - a. Round ductwork: //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick elastomeric//.
 - b. Rectangular ductwork: //2-inch thick mineral fiber board with factory applied FSK// or //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick polyisocyanurate with factory applied ASJ or PVDC// or //1-1/2-inch thick elastomeric//.

- C. Return and Transfer Air Ductwork.
1. Concealed in conditioned locations:
 - a. Round ductwork: None
 - b. Rectangular ductwork: None
 2. Exposed in conditioned locations:
 - a. Round ductwork: None
 - b. Rectangular ductwork: None
 3. Concealed in unconditioned locations:
 - a. Round ductwork: //1-1/2-inch thick mineral fiber blanket with factory applied FSK// or //1-inch thick elastomeric//.
 - b. Rectangular ductwork: //1-inch thick mineral fiber board with factory applied FSK// or //1-1/2-inch thick mineral fiber blanket with factory applied FSK// or //1-inch thick polyisocyanurate with factory applied ASJ or PVDC// or //1-inch thick elastomeric//.
 4. Exposed in unconditioned locations:
 - a. Round ductwork: //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick elastomeric//.
 - b. Rectangular ductwork: //2-inch thick mineral fiber board with factory applied FSK// or //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick polyisocyanurate with factory applied ASJ or PVDC// or //1-1/2-inch thick elastomeric//.
- D. Relief Air and HVAC Exhaust Air Ductwork - between spaces and an exterior wall or roof of the building.
1. Concealed in conditioned locations:
 - a. Round ductwork: None
 - b. Rectangular ductwork: None
 2. Exposed in conditioned locations:
 - a. Round ductwork: None
 - b. Rectangular ductwork: None
 3. Concealed in unconditioned locations:
 - a. Round ductwork: None
 - b. Rectangular ductwork: None
 4. Exposed in unconditioned locations:
 - a. Round ductwork: None
 - b. Rectangular ductwork: None

E. Supply Air Ductwork transporting air that may be up to 15°F warmer than room temperature in the duct, but it is never below room temperature and Outdoor Air Ductwork transporting air that has been treated so it is at room temperature.

1. Concealed in conditioned locations:

- a. Round ductwork: None
- b. Rectangular ductwork: None

2. Exposed in conditioned locations:

- a. Round ductwork: None
- b. Rectangular ductwork: None

3. Concealed in unconditioned locations:

- a. Round ductwork: //1-1/2-inch thick mineral fiber blanket with factory applied FSK// or //1-inch thick elastomeric//.
- b. Rectangular ductwork: //2-inch thick mineral fiber board with factory applied FSK// or //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick polyisocyanurate with factory applied ASJ or PVDC// or //1-1/2-inch thick elastomeric//.

4. Exposed in unconditioned locations:

- a. Round ductwork: //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick elastomeric//.
- b. Rectangular ductwork: //2-inch thick mineral fiber board with factory applied FSK// or //2-inch thick mineral fiber blanket with factory applied FSK// or //1-1/2-inch thick polyisocyanurate with factory applied ASJ or PVDC// or //1-1/2-inch thick elastomeric//.

3.4 INSULATION APPLICATION - PIPING

A. Ground source heat pump condenser water serving ground source heat pumps operating in a range between 4 and 60 degrees C (40 and 140 degrees F).

1. Flexible Elastomeric Cellular Thermal: The thickness of insulation corresponding to the nominal pipe or tube size (inches) is as follows:

- a. Nominal pipe or tube size, less than 1 inch: Insulation thickness of 1 inches.
- b. Nominal pipe or tube size, 1 inch to less than 1-1/2 inch: Insulation thickness of 1 inches.

- c. Nominal pipe or tube size, 1-1/2 inch to less than 4 inch:
Insulation thickness of 1-1/2 inches.
 - d. //Nominal pipe or tube size, 4 inch to less than 8 inch:
Insulation thickness of 1-1/2 inches.//
 - e. //Nominal pipe or tube size, 8 inch to 12 inch: Insulation
thickness of 1-1/2 inches.//
2. Mineral Fiber (Pipe Fitting Insulation and Preformed Pipe Insulation): The thickness of insulation corresponding to the nominal pipe or tube size (inches) is as follows:
- a. Nominal pipe or tube size, less than 1 inch: Insulation thickness of 1 inches.
 - b. Nominal pipe or tube size, 1 inch to less than 1-1/2 inch:
Insulation thickness of 1 inches.
 - c. Nominal pipe or tube size, 1-1/2 inch to less than 4 inch:
Insulation thickness of 1-1/2 inches.
 - d. //Nominal pipe or tube size, 4 inch to less than 8 inch:
Insulation thickness of 1-1/2 inches.//
 - e. //Nominal pipe or tube size, 8 inch to 12 inch: Insulation
thickness of 1-1/2 inches.//
3. Polyisocyanurate Closed-Cell Rigid: The thickness of insulation corresponding to the nominal pipe or tube size (inches) is as follows:
- a. Nominal pipe or tube size, less than 1 inch: Insulation thickness of 3/4 inches.
 - b. Nominal pipe or tube size, 1 inch to less than 1-1/2 inch:
Insulation thickness of 3/4 inches.
 - c. Nominal pipe or tube size, 1-1/2 inch to less than 4 inch:
Insulation thickness of 1 inches.
 - d. //Nominal pipe or tube size, 4 inch to less than 8 inch:
Insulation thickness of 1 inches.//
 - e. //Nominal pipe or tube size, 8 inch to 12 inch: Insulation
thickness of 1 inches.//

PIPE INSULATION TYPE AND THICKNESS SCHEDULE		
INSULATION	PIPE SIZE (NOM. DIA.)	
	LESS THAN 1-1/2-INCH	GREATER THAN 1-1/2-INCH
HEATING WATER		

PIPE INSULATION TYPE AND THICKNESS SCHEDULE		
Mineral Fiber k = 0.27	1-1/2	2
CHILLED WATER, GYCOL SOLUTION, REFRIGERANT		
Flexible Elastomeric maximum k=0.28	2	2
Phenolic maximum k=0.168	1	1
Polyisocyanurate maximum k=0.168	1	1
CONDENSER WATER FOR WATER SOURCE HEAT PUMPS		
Flexible Elastomeric maximum k=0.28	2	2
Phenolic maximum k=0.168	1	1
Polyisocyanurate maximum k=0.168	1	1
COOLING COIL CONDENSATE DRAIN LINES MADE OF COPPER		
Mineral Fiber k = 0.27	1/2	1/2
Flexible Elastomeric maximum k=0.28	1/2	1/2
Phenolic maximum k=0.168	1/2	1/2
Polyisocyanurate maximum k=0.168	1/2	1/2

3.5 INSULATION APPLICATION - MECHANICAL EQUIPMENT

A. Insulate the following HVAC equipment that is not factory insulated:

1. Condenser-water pumps
2. Expansion/compression tanks
3. Air separators
4. Thermal storage tanks

B. Flexible Elastomeric Cellular Thermal: Insulation thickness of 1-1/2 inches.

3.6 //COMMISSIONING

A. Provide commissioning documentation in accordance with the requirements of Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS.

B. Components provided under this section of the specification will be tested as part of a larger system.//

- - - E N D - - -