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SECTION 220700 – PLUMBING INSULATION

PART 1 — GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specifications, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Insulation Materials:

- a. Piping insulation, jacketing and accessories
- b. Equipment insulation and jacketing or coatings
- c. Laminated self-adhesive water and weather seal such as Venture Clad

2. References

- a. ASTM International (ASTM)
- b. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE)
- c. North American Insulation Manufacturers Association (NAIMA)
- d. National Fire Protection Association (NFPA)
- e. Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA)
- f. Underwriter's Laboratories (UL)
- g. GREENGUARD Environmental Institute (GEI)

3. Definitions

- a. Thermal Conductivity (k value): BTU-in. / (hr · ft² · °F)
- b. GEI: GREENGUARD Environmental Institute provides independent, third-party, Indoor Air Quality (IAQ) certification of products for emissions of respirable particles and Volatile Organic Compounds (VOC's), including formaldehyde and other specific product-related pollutants. Certification is based upon criteria used by EPA, OSHA and WHO.
- c. IAQ: Indoor Air Quality
- d. EPA: Environmental Protection Agency
- e. WHO: World Health Organization
- f. ASJ+: All Service Jacket composed of aluminum foil reinforced with glass scrim bonded to a kraft paper interleaving with an outer film layer leaving no paper exposed.
- g. ASJ: All Service Jacket
- h. SSL+: Self-Sealing Advanced Closure System
- i. SSL: Self-Sealing Lap
- j. FSK: Foil-Scrim-Kraft; jacketing
- k. PSK: Poly-Scrim-Kraft; jacketing
- l. PVC: Polyvinyl Chloride
- m. FRP: Fiberglass Reinforced Plastic
- n. ECOSE[®] Technology: a revolutionary binder system based on rapidly renewable bio-based materials rather than petroleum-based chemicals commonly used in other fiber glass insulation products. ECOSE[®] Technology reduces the binder embodied energy by up to 70% and does not contain phenol, formaldehyde, acrylics or artificial colors. Verified to be formaldehyde free by the GEI. Post-consumer recycled glass content is a minimum of 60% verified by UL Environment.
- o. GREENGUARD Indoor Air Quality Certified[®]
A product certification program for low-emitting building materials and other products. GREENGUARD Indoor Air Quality Certified[®] products meet stringent certification requirements and must undergo both annual re-certification and quarterly quality monitoring to ensure ongoing compliance.

- p. GREENGUARD Children & Schools CertifiedSM
A product certification program for low-emitting building materials and other products used in environments where children and other sensitive populations spend extended periods of time. All GREENGUARD Children & Schools CertifiedSM products meet the stringent GREENGUARD Children & Schools Certification requirements, including limits outlined in California's Department of Public Health Services Standard Practice for Specification Section 01350, and undergo both annual re-certification and quarterly quality monitoring to ensure ongoing compliance.
- q. GREENGUARD Formaldehyde Free Verification Requirements
For a product to be verified as formaldehyde free, product samples must have a measured emission factor of less than or equal to 5 µg/m² h at 24 elapsed hours or 3 µg/m² h at 336 elapsed hours. An emission factor of 5 µg/m² h, corresponds to a measured chamber concentration of 2.5 µg/m³ for a typical loading ratio of 0.5 m²/m³. This chamber concentration is comparable to, or below, typical outdoor air concentrations. This demonstrates that the formaldehyde exposure from products labeled as formaldehyde free will not contribute to airborne formaldehyde concentrations at greater levels than those found in the natural outdoor environment.
- r. Underwriter's Laboratories Environment (UL Environment): Offers independent green claims validation, product assessment and certification. UL Environment provides third-party credibility for sustainable products.
- s. UL Environment Environmental Claims Validation (ECV) service and label tests a manufacturer's product and validates that the environmental claims they make in their marketing and packaging materials are factual. This Environmental Claims Validation (ECV) service will allow manufacturers to verify that their products contain a quantifiable amount of recycled content and, as such, help limit raw material extraction and reduce landfill waste. It will also enable products to qualify for LEED[®] points under Pilot Credit 43: MR – Certified Products.
- t. EUCEB: Exonerated fiber from a health and safety standpoint by the European Certification Board process.
- u. Recycled content – post-consumer: Materials such as bottled glass collected at curbside or other collection sites after consumer use and used in the manufacturing process to create a new product rather than being placed in a landfill or incinerated.
- v. Recycled content – pre-consumer (aka post-industrial): Materials used or created from one manufacturing process which are collected as scrap and placed back into another manufacturing process rather than being placed in a landfill or incinerated.
- w. This product does not contain polybrominated diphenyl ethers (PBDE) such as: Penta-BDE, Octa-BDE or Deca-BDE fire retardants.

B. Related Sections:

1. Division 23 Section "HVAC Insulation"

1.3 SUBMITTALS FOR INFORMATION

- A. Product data: To include product description, manufacturer's installation instructions, types and recommended thicknesses for each application, and location of materials.
- B. Samples and mock-ups of systems shall be provided upon engineer's request.

1.4 QUALITY ASSURANCE

- A. Surface Burning Characteristics: Insulation and related materials shall have surface burning characteristics determined by test performed on identical products per ASTM E 84 mounted and installed as per ASTM E 2231. All testing shall be performed by a testing and inspecting agency acceptable to authorities having jurisdiction. Insulation, jacket materials, adhesives, mastics, tapes and cement material containers shall be labeled with appropriate markings of applicable testing and inspecting agency.
 1. Insulation installed indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.

2. Insulation installed outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.
- B. Store tapes, adhesives, mastics, cements, and insulation materials in ambient conditions in accordance with the recommendations of the manufacturer.
- C. Follow manufacturer's recommended handling practices.
- D. Supply fiber glass products that are manufactured using a minimum of 60% "post-consumer" recycled glass material.
- E. Supply fiber glass products that have a bio-based binder rather than non-renewable petroleum-based chemicals and with a binder that does not contain phenol, formaldehyde, or acrylics.
- F. Supply fiber glass products that have achieved GREENGUARD Children & Schools Certification. Verified to be formaldehyde free by the GEI.
- G. Fiber Glass and Mold: Contractor shall take precaution to protect insulation materials from moisture exposure or physical damage. Any fiber glass insulation that becomes wet or damaged shall be replaced at no additional cost.
 1. HVAC duct work insulation used in the air stream must be discarded if exposed to liquid water.
 2. Pipe Insulation with factory applied ASJ+ facing having been fully installed with all pipe insulation system joints (including fittings, flanges, valves, and other in-line devices) sealed per manufacturer's installation recommendation which may experience casual and intermittent exposure to liquid water after installation may be exempted from removal and replacement. Contractor must be prepared to provide proof that insulation glass fiber has not been exposed to liquid water.

PART 2 — PRODUCTS

2.1 INSULATION MATERIALS

- A. Products shall not contain 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 parts per million (ppm) when tested according to ASTM C 871.
- C. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
- D. Manufacturers: Knauf Insulation, Proto Corporation, or pre-approved substitute.
- E. Glass Fiber: Knauf Insulation Earthwool® 1000° Pipe Insulation with ECOSE® Technology meeting ASTM C 547 Type IV Grade A, ASTM C 585, and ASTM C 795; rigid, molded, k value: ASTM C 335, 0.23 at 75°F (0.033 at 24°C) mean temperature. Maximum Service Temperature: 1000°F (538°C). Vapor Retarder Jacket: ASJ+/SSL+ conforming to ASTM C 1136 Type I, II, & VIII secured with self-sealing longitudinal laps and matching ASJ+ butt strips. Verified to be formaldehyde free by the GEI.
- F. Glass Fiber: Knauf Insulation Earthwool® Redi-Klad® 1000° Pipe Insulation with ECOSE® Technology meeting ASTM C 547 Type IV Grade A, ASTM C 585, and ASTM C 795; rigid, molded. k value: ASTM C 335, 0.23 at 75° F (0.033 at 24° C) mean temperature. Maximum Service Temperature: 1000° F (538° C). Redi-Klad® Jacket: 5-ply weather and abuse resistant with self-seal lap. Zero permeability per ASTM E 96-05; puncture resistance 35.4 kg (189.3 N) per ASTM D 1000; tear strength 4.3 lb. (19.4 N) per ASTM D 624; thickness 14.5 mils (0.0145"); tensile strength 68.0 lb./inch width [306 N (31 kg)/25 mm]. Verified to be formaldehyde free by the GEI.
- G. Glass Fiber: Knauf Insulation Pipe & Tank Insulation with ECOSE® Technology; semi-rigid, limited combustible meeting requirements of NRC 1.36; ASTM C 795 and MIL-I-24244 C. k value: ASTM C 177, 0.25 at 75° F (0.036 at 24°C) mean temperature. Maximum Service Temperature: 850°F (454°C). Compressive Strength: not less than 150 PSF (7.18 kPa) @ 10% deformation for 2 inch (51 mm) thickness per ASTM C 165. Vapor Retarder Jacket: ASJ conforming to ASTM C 1136 Type II. Verified to be formaldehyde free by the GEI.
- H. Glass Fiber: Knauf Insulation KwikFlex® Pipe & Tank Insulation with ECOSE® Technology; semi-rigid fiber glass blanket in roll form meeting requirements of ASTM E 84; UL 723, ASTM C 1393 and ASTM C 356. k value: ASTM C 516, 0.24 at 75° F (0.035 at 24°C) mean

temperature. Maximum Service Temperature: 850°F (454°C); maximum surface temperature for faced product: 150° F (66° C); maximum thickness @ 850° F: 4 inches (102 mm). Compressive Strength: not less than 25 PSF (1.2 kPa) @ 10% deformation per ASTM C 165. Vapor Retarder Jacket: ASJ, FSK or PSK conforming to ASTM E 96, Procedure A. Verified to be formaldehyde free by the GEI.

- I. Fitting Insulation: Insulate using pre-formed PVC fitting covers with fiberglass inserts. Alternatively, preformed molded fiber glass or mitered fiber glass pipe insulation sections. These fittings shall be further protected by field-applied PVC fitting covers, metal fitting covers, or glass fabric and mastic sealed as necessary.

2.2 FACTORY APPLIED JACKETS

- A. ASJ+/SSL+: All service jacket with self-sealing lap. All Service Jacket composed of aluminum foil reinforced with glass scrim bonded to a kraft paper interleaving with an outer film layer leaving no paper exposed.; conforming to ASTM C 1136 Type I, II, and VIII; vapor retarder; with a self-sealing adhesive.
- B. ASJ: All service jacket. White-kraft paper bonded to aluminum foil and reinforced with glass fibers; conforming to ASTM C 1136; vapor retarder.
- C. FSK: Foil scrim kraft. Aluminum foil, fiberglass reinforced scrim with kraft backing; conforming to ASTM C 1136 Type 1; vapor retarder.
- D. PSK: Poly scrim kraft. Metalized polypropylene, fiberglass reinforced scrim with kraft backing; conforming to ASTM C 1136 Type 1; vapor retarder.
- E. Redi-Klad[®] Jacket: 5-ply weather and abuse resistant with self-seal lap. Zero permeability per ASTM E 96-05; puncture resistance 35.4 kg (189.3 N) per ASTM D 1000; tear strength 4.3 lb. (19.4 N) per ASTM D 624; thickness 14.5 mils (0.0145"); tensile strength 68.0 lb./inch width [306 N (31 kg)/25 mm].

2.3 FIELD APPLIED JACKETS

- A. Fire retardant Information: This product does not contain polybrominated diphenyl ethers (PBDE) such as: Penta-BDE, Octa-BDE or Deca-BDE.
- B. PVC: Proto Corporation 25/50 or Indoor/Outdoor, UV-resistant fittings, jacketing and accessories, white or colored. Fitting cover system consists of pre-molded, high-impact PVC materials with fiber glass inserts. Fiber glass insert has a thermal conductivity (k value) of 0.26 at 75° F (0.037 at 24°C) mean temperature. Closures: stainless steel tacks, matching PVC tape, or PVC adhesive per manufacturer's recommendations.
- C. Metal: Aluminum, 0.016-inch (0.406 mm) thick or Stainless Steel, 0.010-inch (0.254 mm) thick in smooth, corrugated, or embossed finish with factory-applied moisture barrier. Overlap shall be 2-inch (50 mm) minimum. Fittings shall be die-shaped with factory-applied moisture barrier.
- D. Laminated Self-Adhesive Water and Weather Seals: permanent acrylic self-adhesive system; weather resistant, high puncture and tear resistance; meeting or exceeding requirements of UL 723; applied in strict accordance with manufacturers' recommendations.

PART 3 — EXECUTION

3.1 EXAMINATION

- A. Verify that all piping and equipment are tested and approved prior to insulation installation.
- B. Verify that all surfaces are clean, dry and without foreign material before applying insulation materials.

3.2 GENERAL INSULATION REQUIREMENTS

- A. All materials shall be installed by skilled labor regularly engaged in this type of work. All materials shall be installed in strict accordance with manufacturer's recommendations, building codes, and industry standards.
- B. Locate insulation and cover seams in the least visible location. All surface finishes shall be extended in such a manner as to protect all raw edges, ends and surfaces of insulation.
- C. On cold surfaces where a vapor seal must be maintained, insulation shall be applied with a continuous, unbroken moisture and vapor retarder. All hangers, supports, anchors, or other

projections secured to cold surfaces shall be insulated and vapor sealed to prevent condensation.

- D. All pipe insulation shall be continuous through walls, ceiling or floor openings, or sleeves except where firestop or firesafing materials are required.
- E. Install multiple layers of insulation with longitudinal and circumferential joints staggered.

3.3 PIPING INSULATION: 1000° PIPE INSULATION AND REDI-KLAD® PIPE INSULATION

- A. Locate all seams in the least visible location.
- B. Insulation installed on piping operating below ambient temperatures must have a continuous vapor retarder. All joints, seams and fittings must be sealed. On systems operating above ambient, the butt joints should not be sealed.
- C. On high-temperature piping, above 500°F (260°C), insulation shall be applied using double-layer with staggered joints. When double layering, the inner layer should not be jacketed. All joints and ends must be firmly butted and secured with appropriate securement material.
- D. Metal shields shall be installed between hangers or supports and the piping insulation. Rigid insulation inserts shall be installed as required between the pipe and the insulation shields. Inserts shall be of equal thickness to the adjacent insulation and shall be vapor sealed as required. Insulation inserts shall be no less than the following lengths:

1½" to 2½" IPS	10" long
3" to 6" IPS	12" long
8" to 10" IPS	16" long
12" and over IPS	22" long
- E. For piping exposed in mechanical rooms or high traffic areas, insulation shall be protected from abuse by the use of appropriate thickness of PVC jacketing, metal jacketing or laminated self-adhesive water and weather seals.
- F. For piping exposed to the elements install Redi-Klad® with 4" butt strips and self sealing lap or a jacketing that shall be UV resistant PVC with a minimum thickness of 0.020 inches, or 0.016 inches (0.406) thick aluminum with factory applied moisture barrier or 0.010 inches (0.254mm) thick stainless steel with a factory applied moisture barrier. Fitting covers shall be of similar materials. The insulation and jacketing shall be held firmly in place with a friction type Z lock or a minimum 2" overlap joint. For systems operating below ambient, all PVC joints shall be sealed completely along the longitudinal and circumferential seams and installed so as to shed water. When required, all PVC circumferential joints shall be sealed by use of preformed butt strips; minimum 2" wide or a minimum 2" overlap. Butt strips shall overlap the adjacent jacketing a minimum ½ inch and be completely weather sealed. PVC Jacketing shall be limited to a maximum 20-inch OD of the insulation when exposed to direct sunlight. For systems operating above ambient, circumferential joints should overlap a minimum of 2" and not be sealed. Insulation thickness for piping covered by PVC Jacketing shall be such that the surface temperature of the PVC does not exceed 125°F (52°C).
- G. Insulate valves, balancing valves and other devices requiring access with removable covers. Covers shall have a minimum k-factor of .26 using fiberglass blanket. Flame and smoke spread shall be 25/50 per ASTM E-84. Covers shall be completely overlapping and completely cover the adjacent insulation with seams and butt ends secure.
- H. Cold Piping Installation / High Abuse Systems
 - 1. On systems operating below freezing or systems operating in high abuse areas install Redi-Klad® with 4" butt strips and self sealing lap; or the ASJ+ jacket shall be protected with a PVC vapor retarding outer jacket. In addition, exposed ends of the insulation shall be sealed with a vapor retarder mastic installed per the manufacturer's recommendations. Vapor stops, vapor retarder mastic applied in the insulation butt joint from the vapor retarder jacket to the pipe, shall be applied at every fourth pipe section joint and at each fitting to isolate any water incursion or transmission.
 - 2. On systems operating below ambient and in conditions of Design RH of 90% and above, it is recommended that the same guidelines be followed as listed above for below freezing applications.

3.4 PIPING INSULATION: PIPE & TANK INSULATION AND KWIKFLEX® PIPE & TANK INSULATION

- A. Apply on clean, dry surfaces.
- B. Cut to appropriate length using manufacturers' stretchout guide for the specific pipe size. Add an additional 2 inches (51 mm) to 4 inches (102 mm) for a staple flap.
- C. Wrap around the pipe to ensure proper fit. Staple the lap on 3 inch (76 mm) centers with outward clinching staples.
- D. Ends shall be firmly butted and secured with matching butt strip material at each joint.
- E. For piping exposed to the elements, jacketing shall be UV resistant PVC with a minimum thickness of 0.020 inches, or 0.016 inches (0.406) thick aluminum with factory applied moisture barrier or 0.010 inches (0.254mm) thick stainless steel with a factory applied moisture barrier or laminated self-adhesive water and weather seals. Fitting covers shall be of similar materials. The insulation and jacketing shall be held firmly in place with a friction type Z lock or a minimum 2" overlap joint. For systems operating below ambient, all PVC joints shall be sealed completely along the longitudinal and circumferential seams and installed so as to shed water. When required, all PVC circumferential joints shall be sealed by use of preformed butt strips; minimum 2" wide or a minimum 2" overlap. Butt strips shall overlap the adjacent jacketing a minimum ½ inch and be completely weather sealed. PVC Jacketing shall be limited to a maximum 20-inch OD of the insulation when exposed to direct sunlight. For systems operating above ambient, circumferential joints should overlap a minimum of 2" and not be sealed. Insulation thickness for piping covered by PVC Jacketing shall be such that the surface temperature of the PVC does not exceed 125°F (52°C).
- F. On below ambient piping, vapor retarder mastic shall be applied to the ends at every fourth section and at each fitting before taping.

3.5 EQUIPMENT INSULATION - FIBER GLASS

- A. Apply insulation to the equipment surface with joints firmly butted and as close as possible to the equipment surface. Insulation shall be secured as required with mechanical fasteners or banding material. Fasteners shall be located a maximum of 3" from each edge and spaced no greater than 12" on center.
- B. For below ambient systems, vapor retarder jacketing shall overlap a minimum of 2" at all seams and be sealed with appropriate pressure-sensitive tape or mastic. All penetrations and facing damage shall be covered with a minimum 2" (51mm) overlap of tape or mastic.
- C. Equipment insulation exposed to the elements shall be finished with minimum 0.030-inch thick, outdoor, weather resistant PVC; laminated self-adhesive water based weatherproof mastic and glass cloth; or metal. All longitudinal joints shall be positioned so as to shed water; with a minimum 3" overlap, and completely weather sealed. Laminated systems shall be applied per manufacturer's recommendations.
- D. For high-temperature applications, insulation may either be mounted in direct contact with the hot surface, in H-bar configuration, or pre-fabricated panel systems mounted away from the operating surface. When installing H-Bar or panel systems which are mounted away from the operating surface, convection stops shall be installed at a maximum of 8 feet along the vertical surfaces. Insulation may be applied over welded pins or studs up to ½" in diameter. Insulation shall be held in place using mesh reinforcement or steel bands. Insulation shall not be compressed beyond a maximum of 1/8 inch at any point. Pins and studs shall be spaced a maximum of 4" from each edge and no greater than 16" on center. For temperatures above 500°F (260°C) and design thicknesses over 3", insulation shall be applied using double-layer with staggered joints. Finish shall be minimum 0.020-inch thick PVC jacketing, insulating cement with canvas, glass cloth with mastic, or metal as specified on the drawings.
- E. For Equipment insulation exposed in mechanical rooms or subject to mechanical abuse, finish with minimum 0.020 inch thick PVC jacketing or metal or laminated self-adhesive water and weather seals. All other insulation shall be finished as appropriate for the location and service or as specified on the drawings.

3.6 INSULATION SCHEDULES

A. ASHRAE 90.1 – 2010 Requirements, Pipe Insulation

1. The minimum insulation thickness based upon ASHRAE 90.1 **do not necessarily represent the Economic Thickness of Insulation or the thickness required for proper condensation control**. Rather, they serve as minimum recommendations for commercial applications. For recommended Economic Thickness and System Design, install according to NAIMA 3E Plus or as specified.

Minimum Pipe Insulation Thickness^a

Fluid Design Operating Temp. Range (° F.)	Insulation Conductivity		Nominal Pipe or Tube Size (in.)				
	Conductivity Btu-in./(hr-ft ² .°F)	Mean Rating Temp. °F.	<1	1 to < 1½	1½ to < 4	4 to <8	≥8
Heating Hot Water Systems (Steam, Steam Condensate, Hot Water Heating and Domestic Water Systems)^{b,c}							
>350	0.32 – 0.34	250	4.5	5.0	5.0	5.0	5.0
251 – 350	0.29 – 0.31	200	3.0	4.0	4.5	4.5	4.5
201 – 250	0.27 – 0.30	150	2.5	2.5	2.5	3.0	3.0
141 – 200	0.25 – 0.29	125	1.5	1.5	2.0	2.0	2.0
105 – 140	0.22 – 0.28	100	1.0	1.0	1.5	1.5	1.5
Cooling Systems (Chilled Water, Brine, and Refrigerant)^d							
40 – 60	0.21 – 0.27	75	0.5	0.5	1.0	1.0	1.0
<40	0.20 – 0.26	50	0.5	1.0	1.0	1.0	1.5

^a For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows: $T = r\{(1 + t/r)^{K/k} - 1\}$. Where T = minimum insulation thickness (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature {Btu-in.(hr-ft².°F)}; and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.

^b These thicknesses are based on energy *efficiency* considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.

^c For piping smaller than 1.5” and located in partitions within conditioned spaces, reduction of these thicknesses by 1” shall be permitted (before thickness adjustment required in footnote a) but not to thicknesses below 1”.

^d These thicknesses are based on energy *efficiency* considerations only. **Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.**

^e The table is based on steel pipe. Non-metallic pipes scheduled 80 thickness or less shall use the table values. For other non-metallic pipes having thermal resistance greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown on the table.

NECESSARY PIPE INSULATION THICKNESS TO PREVENT CONDENSATION:

Jacket: ASJ+ ($\epsilon = 0.9$) Wind Speed = 0 mph Ambient Temperature = 80°F

Pipe Size	Relative Humidity & Operating Temperature					Relative Humidity & Operating Temperature					Relative Humidity & Operating Temperature				
	70% RH					80% RH					90% RH				
	35°F	40°F	45°F	50°F	55°F	35°F	40°F	45°F	50°F	55°F	35°F	40°F	45°F	50°F	55°F
0.5	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	0.5"	0.5"	1.5"	1.5"	1.5"	1.0"	1.0"
1	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	0.5"	0.5"	1.5"	1.5"	1.5"	1.5"	1.0"
1.5	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	0.5"	2.0"	2.0"	1.5"	1.5"	1.5"
2	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	0.5"	2.0"	2.0"	1.5"	1.5"	1.5"
4	1.0"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	0.5"	2.0"	2.0"	2.0"	1.5"	1.5"
6	1.0"	0.5"	0.5"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	0.5"	2.5"	2.5"	2.0"	2.0"	1.5"
8	1.0"	0.5"	0.5"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	0.5"	2.5"	2.5"	2.0"	2.0"	1.5"
10	1.0"	0.5"	0.5"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	0.5"	2.5"	2.5"	2.0"	2.0"	1.5"
12	1.0"	1.0"	1.0"	1.0"	0.5"	1.5"	1.0"	1.0"	1.0"	1.0"	2.5"	2.5"	2.0"	2.0"	1.5"

Jacket: ASJ+ ($\epsilon = 0.9$) Wind Speed = 0 mph Ambient Temperature = 90°F

Pipe Size	Relative Humidity & Operating Temperature					Relative Humidity & Operating Temperature					Relative Humidity & Operating Temperature				
	70% RH					80% RH					90% RH				
	35°F	40°F	45°F	50°F	55°F	35°F	40°F	45°F	50°F	55°F	35°F	40°F	45°F	50°F	55°F
0.5	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	0.5"	0.5"	2.0"	1.5"	1.5"	1.0"	1.0"
1	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	0.5"	2.0"	2.0"	2.0"	1.5"	1.5"
1.5	1.0"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	1.0"	2.0"	2.0"	2.0"	2.0"	1.5"
2	1.0"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	1.0"	2.5"	2.0"	2.0"	2.0"	1.5"
4	1.0"	0.5"	0.5"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	1.0"	3.0"	2.5"	2.5"	2.0"	2.0"
6	1.0"	1.0"	0.5"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	1.0"	3.0"	3.0"	2.5"	2.5"	2.0"
8	1.0"	1.0"	1.0"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	1.0"	3.0"	3.0"	2.5"	2.5"	2.0"
10	1.0"	1.0"	1.0"	0.5"	0.5"	1.5"	1.5"	1.0"	1.0"	1.0"	3.5"	3.0"	2.5"	2.5"	2.0"
12	1.0"	1.0"	1.0"	1.0"	0.5"	1.5"	1.5"	1.0"	1.0"	1.0"	3.5"	3.0"	2.5"	2.5"	2.0"

B. EQUIPMENT INSULATION SCHEDULE:

1. As noted on the drawings or per ASHRAE 90.1 Schedule.

END OF SECTION 220700

SECTION 230700 - HVAC INSULATION

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SECTION 230700 - HVAC INSULATION

PART 1 — GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specifications, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Insulation Materials:
 - a. Piping insulation, jacketing and accessories
 - b. Equipment insulation and jacketing or coatings
 - c. Laminated self-adhesive water and weather seal: such as Venture Clad
2. References
 - a. ASTM International (ASTM)
 - b. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE)
 - c. North American Insulation Manufacturers Association (NAIMA)
 - d. National Fire Protection Association (NFPA)
 - e. Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA)
 - f. Underwriter's Laboratories (UL)
 - g. GREENGUARD Environmental Institute (GEI)
3. Definitions
 - a. Thermal conductivity (k value): BTU-in. / (hr · ft² · °F)
 - b. GREENGUARD: GREENGUARD Environmental Institute provides independent, third-party, Indoor Air Quality (IAQ) certification of products for emissions of respirable particles and Volatile Organic Compounds (VOC's), including formaldehyde and other specific product-related pollutants. Certification is based upon criteria used by EPA, OSHA and WHO.
 - c. IAQ: Indoor Air Quality
 - d. EPA: Environmental Protection Agency
 - e. WHO: World Health Organization
 - f. ASJ+: All Service Jacket composed of aluminum foil reinforced with glass scrim bonded to a kraft paper interleaving with an outer film layer leaving no paper exposed.
 - g. ASJ: All Service Jacket
 - h. SSL+: Self-Sealing Advanced Closure System
 - i. SSL: Self-Sealing Lap
 - j. FSK: Foil-Scrim-Kraft; jacketing
 - k. PSK: Poly-Scrim-Kraft; jacketing
 - l. PVC: Polyvinyl Chloride
 - m. FRP: Fiberglass Reinforced Plastic
 - n. ECOSE[®] Technology: a revolutionary binder system based on rapidly renewable bio-based materials rather than petroleum-based chemicals commonly used in other fiber glass insulation products. ECOSE[®] Technology reduces the binder embodied energy by up to 70% and does not contain phenol, formaldehyde, acrylics or artificial colors. Verified to be formaldehyde free by the GEI. Post-consumer recycled glass content is a minimum of 60% verified by UL Environment.
 - o. GREENGUARD Indoor Air Quality Certified[®]
A product certification program for low-emitting building materials and other products. GREENGUARD Indoor Air Quality Certified[®] products meet stringent certification requirements and must undergo both annual re-certification and quarterly quality monitoring to ensure ongoing compliance.

- p. GREENGUARD Children & Schools CertifiedSM
A product certification program for low-emitting building materials and other products used in environments where children and other sensitive populations spend extended periods of time. All GREENGUARD Children & Schools CertifiedSM products meet the stringent GREENGUARD Children & Schools Certification requirements, including limits outlined in California's Department of Public Health Services Standard Practice for Specification Section 01350, and undergo both annual re-certification and quarterly quality monitoring to ensure ongoing compliance.
- q. GREENGUARD Formaldehyde Free Verification Requirements
For a product to be verified as formaldehyde free, product samples must have a measured emission factor of less than or equal to 5 µg/m² h at 24 elapsed hours or 3 µg/m² h at 336 elapsed hours. An emission factor of 5 µg/m² h, corresponds to a measured chamber concentration of 2.5 µg/m³ for a typical loading ratio of 0.5 m²/m³. This chamber concentration is comparable to, or below, typical outdoor air concentrations. This demonstrates that the formaldehyde exposure from products labeled as formaldehyde free will not contribute to airborne formaldehyde concentrations at greater levels than those found in the natural outdoor environment.
- r. Underwriter's Laboratories Environment (UL Environment): Offers independent green claims validation, product assessment and certification. UL Environment provides third-party credibility for sustainable products.
- s. UL Environment Environmental Claims Validation (ECV) service and label tests a manufacturer's product and validates that the environmental claims they make in their marketing and packaging materials are factual. This Environmental Claims Validation (ECV) service will allow manufacturers to verify that their products contain a quantifiable amount of recycled content and, as such, help limit raw material extraction and reduce landfill waste. It will also enable products to qualify for LEED[®] points under Pilot Credit 43: MR – Certified Products.
- t. EUCEB: Exonerated fiber from a health and safety standpoint by the European Certification Board process.
- u. Recycled content – post-consumer: Materials such as bottled glass collected at curbside or other collection sites after consumer use and used in the manufacturing process to create a new product rather than being placed in a landfill or incinerated.
- v. Recycled content – pre-consumer (aka post-industrial): Materials used or created from one manufacturing process which are collected as scrap and placed back into another manufacturing process rather than being placed in a landfill or incinerated.
- w. This product does not contain polybrominated diphenyl ethers (PBDE) such as: Penta-BDE, Octa-BDE or Deca-BDE fire retardants.

B. Related Sections:

- 1. Division 22 Section "Plumbing Insulation"

1.3 SUBMITTALS FOR INFORMATION

- A. Product data: To include product description, manufacturer's installation instructions, types and recommended thicknesses for each application, and location of materials.
- B. Samples and mock-ups of systems shall be provided upon engineer's request.

1.4 QUALITY ASSURANCE

- A. Surface Burning Characteristics: Insulation and related materials shall have surface burning characteristics determined by test performed on identical products per ASTM E 84 mounted and installed as per ASTM E 2231. All testing shall be performed by a testing and inspecting agency acceptable to authorities having jurisdiction. Insulation, jacket materials, adhesives, mastics, tapes and cement material containers shall be labeled with appropriate markings of applicable testing and inspecting agency.
 - 1. Insulation installed indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.

2. Insulation installed outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.
- B. Store tapes, adhesives, mastics, cements, and insulation materials in ambient conditions in accordance with the recommendations of the manufacturer.
- C. Follow manufacturer's recommended handling practices.
- D. Supply fiber glass products that are manufactured using a minimum of 60% "post-consumer" recycled bottle glass material.
- E. ECOSE[®] Technology: a revolutionary binder system based on rapidly renewable bio-based materials rather than petroleum-based chemicals commonly used in other fiber glass insulation products. ECOSE[®] Technology reduces the binder embodied energy by up to 70% and does not contain phenol, formaldehyde, acrylics or artificial colors. Verified to be formaldehyde free by the GEI. Post-consumer recycled glass content is a minimum of 60% verified by UL Environment.
- F. Supply fiber glass products that have achieved GREENGUARD Children & Schools CertificationSM. Verified to be formaldehyde free by the GEI.
- G. Fiber Glass and Mold: Contractor shall take precaution to protect insulation. Any fiber glass insulation that becomes wet or torn should be replaced at no additional cost. **Air handling insulation used in the air stream must be discarded if exposed to water.**

PART 2 — PRODUCTS

2.1 INSULATION MATERIALS

- A. Products shall not contain asbestos, lead, formaldehyde, mercury or mercury compounds.
- B. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 parts per million (ppm) when tested according to ASTM C 871.
- C. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
- D. Manufacturers: Knauf Insulation, Proto Corporation, or pre-approved substitute.
- E. Glass Fiber: Knauf Insulation Earthwool[®] 1000° Pipe Insulation with ECOSE[®] Technology meeting ASTM C 547 Type IV Grade A, ASTM C 585, and ASTM C 795; rigid, molded. k value: ASTM C 335, 0.23 at 75°F (0.033 at 24°C) mean temperature. Maximum Service Temperature: 1000°F (538°C). Vapor Retarder Jacket: ASJ+/SSL+ conforming to ASTM C 1136 Type I, II, & VIII secured with self-sealing longitudinal laps and matching ASJ+ butt strips. Verified to be formaldehyde free by the GEI.
- F. Glass Fiber: Knauf Insulation Earthwool[®] Redi-Klad[®] 1000° Pipe Insulation with ECOSE[®] Technology meeting ASTM C 547, ASTM C 585, and ASTM C 795; rigid, molded. k value: ASTM C 335, 0.23 at 75° F (0.033 at 24° C) mean temperature. Maximum Service Temperature: 1000° F (538° C). Redi-Klad[®] Jacket: 5-ply weather and abuse resistant with self-seal lap. Zero permeability per ASTM E 96-05; puncture resistance 35.4 kg (189.3 N) per ASTM D 1000; tear strength 4.3 lb. (19.4 N) per ASTM D 624; thickness 14.5 mils (0.0145"); tensile strength 68.0 lb./inch width [306 N (31 kg)/25 mm]. Verified to be formaldehyde free by the GEI.
- G. Glass Fiber: Knauf Insulation Pipe & Tank Insulation with ECOSE[®] Technology; semi-rigid, limited combustibles meeting requirements of NRC 1.36; ASTM C 795 and MIL-I-24244 C. k value: ASTM C 177, 0.25 at 75° F (0.036 at 24°C) mean temperature. Maximum Service Temperature: 850°F (454°C). Compressive Strength: not less than 150 PSF (7.18 kPa) @ 10% deformation for 2 inch (51 mm) thickness per ASTM C 165. Vapor Retarder Jacket: ASJ conforming to ASTM C 1136 Type II. Verified to be formaldehyde free by the GEI.
- H. Glass Fiber: Knauf Insulation KwikFlex[®] Pipe & Tank Insulation with ECOSE[®] Technology; semi-rigid fiber glass blanket in roll form meeting requirements of ASTM E 84; UL 723, ASTM C 1393 and ASTM C 356. k value: ASTM C 516, 0.24 at 75° F (0.035 at 24°C) mean temperature. Maximum Service Temperature: 850°F (454°C); maximum surface temperature for faced product: 150°F (66° C); maximum thickness @ 850° F: 4 inches (102 mm). Compressive Strength: not less than 25 PSF (1.2 kPa) @ 10% deformation per ASTM C 165.

- Vapor Retarder Jacket: ASJ, FSK or PSK conforming to ASTM E 96, Procedure A. Verified to be formaldehyde free by the GEI.
- I. Fitting Insulation: Insulate using pre-formed PVC fitting covers with fiber glass inserts. Alternatively, preformed fiber glass, mitered fiber glass, pre-formed perlite, mitered perlite or calcium silicate may be used for some applications depending on the service conditions. These fittings shall be further protected by field-applied fitting covers or metal fittings as necessary.
 - J. Rigid Fiber Glass Board: Knauf Insulation Insulation Board with ECOSE[®] Technology meeting ASTM C 612 Type IA and IB; rigid.
Maximum Service Temperature: 450° F (232° C).
 - 1. Concealed Areas: Density: Minimum 3 PCF (48 kg/m3). k value: ASTM C 177, 0.23 at 75° F (0.033 at 24° C) mean temperature. Vapor Retarder Jacket: ASJ conforming to ASTM C 1136 Type I, or FSK or PSK conforming to ASTM C 1136 Type II.
 - 2. Exposed Areas: Density: Minimum 6 PCF (96 kg/m3). k value: ASTM C 177, 0.22 at 75° F (0.032 at 24° C) mean temperature. Vapor Retarder Jacket: ASJ conforming to ASTM C 1136 Type I, or FSK or PSK conforming to ASTM C 1136 Type II in combination with protective jacket where necessary.
 - K. Rigid Fiber Glass Board: Knauf Insulation Elevated Temperature (ET) Board 1000° with ECOSE[®] Technology meeting ASTM C 612 Type IA, IB, and II; rigid, noncombustible.
Maximum Service Temperature: 1000° F (538° C). Density: 2.8 PCF (45 kg/m3). k value: ASTM C 177, 0.25 at 100° F (0.036 at 38° C) mean temperature. Verified to be formaldehyde free by the GEI.
 - L. Semi-Rigid Fiber Glass Board: Knauf Insulation Elevated Temperature (ET) Panel 1000° with ECOSE[®] Technology meeting ASTM C 612 Type II and III; semi-rigid, noncombustible.
Maximum Service Temperature: 1000° F (538° C). Density: 2.4 PCF (38 kg/m3). k value: ASTM C 177, 0.25 at 100° F (0.036 at 38° C) mean temperature. Verified to be formaldehyde free by the GEI.
 - M. Flexible Fiber Glass Blanket: Knauf Insulation Elevated Temperature (ET) Blanket 1000° with ECOSE[®] Technology; flexible, noncombustible. Maximum Service Temperature: 1000° F (538° C). Density: 1.1 PCF (18 kg/m3). k value: ASTM C 177, 0.28 at 100° F (0.040 at 38° C) mean temperature. Verified to be formaldehyde free by the GEI.
 - N. Flexible Fiber Glass Blanket: Knauf Insulation Friendly Feel[®] Duct Wrap with ECOSE[®] Technology meeting ASTM C 553 Types I, II and III, and ASTM C 1290; GREENGUARD certified; flexible, limited combustibile. k value: ASTM C 177, 0.29 at 75° F (0.042 at 24°C) mean temperature. Maximum Service Temperature: faced: 250°F (121°C); unfaced: 350°F (177°C). Vapor Retarder Jacket: FSK or PSK conforming to ASTM C 1136 Type II. Installation: Maximum allowable compression is 25%. Securement: Secured in place using outward cinching staples in combination with appropriate pressure-sensitive aluminum foil or PSK tape, or in combination with glass fabric and vapor retarder mastic. Density: concealed areas: Minimum 0.75 PCF (12 kg/m3); exposed areas: Minimum 1.0 PCF (16 kg/m3). Verified to be formaldehyde free by the GEI.
 - O. Knauf Insulation Sonic XP[™] Duct Liner with ECOSE[®] Technology conforming to ASTM C 1071 Type I and NFPA 90A & 90B; GREENGUARD certified, or Knauf Insulation Rigid Plenum Liner with ECOSE[®] Technology complying with ASTM C 1071 Type II and NFPA 90A & 90B. k value: ASTM C 177, 0.24 at 75°F (0.035 at 24°C) mean temperature. Noise Reduction Coefficient (NRC): ASTM C 423 Type A Mounting, 0.45 or higher for ½" product, 0.70 or higher for 1" product. Maximum Air Velocity: 6000 FPM (1829 mpm) for Type I product, 5000 FPM (1524 mpm) for Type II product.
 - P. Fiber Glass Ductwork: Knauf Insulation Eclipse[®] Air Duct Board with ECOSE[®] Technology or Knauf Insulation Air Duct Board M with ECOSE[®] Technology. Product shall conform to UL-181 Class 1 and NFPA 90A & 90B and be GREENGUARD certified. k value: ASTM C 177, 0.23 at 75°F (0.033 at 24°C) mean temperature. Maximum Temperature: 250°F (121°C). Maximum Internal Static Pressure: +/- 2" water gauge. Maximum Air Velocity: 5000 FPM (1524 mpm). Type shall be EI-475 with FSK facing. In applications where additional rigidity is required, for large spans, where extra strength is needed, or where energy codes require R-6 or greater, type shall be EI-800.

2.2 FACTORY APPLIED JACKETS

- A. ASJ+/SSL+: All service jacket with self-sealing lap. All Service Jacket composed of aluminum foil reinforced with glass scrim bonded to a kraft paper interleaving with an outer film layer leaving no paper exposed; conforming to ASTM C 1136 Type I, II, III, IV & VIII; vapor retarder; with a self-sealing adhesive.
- B. ASJ: All service jacket. White-kraft paper bonded to aluminum foil and reinforced with glass fibers; conforming to ASTM C 1136; vapor retarder.
- C. FSK: Foil scrim kraft. Aluminum foil, fiberglass reinforced scrim with kraft backing; conforming to ASTM C 1136 Type 1; vapor retarder.
- D. PSK: Poly scrim kraft. Metalized polypropylene, fiberglass reinforced scrim with kraft backing; conforming to ASTM C 1136 Type 1; vapor retarder.
- E. Redi-Klad[®] Jacket: 5-ply weather and abuse resistant with self-seal lap. Zero permeability per ASTM E 96-05; puncture resistance 35.4 kg (189.3 N) per ASTM D 1000; tear strength 4.3 lb. (19.4 N) per ASTM D 624; thickness 14.5 mils (0.0145"); tensile strength 68.0 lb./inch width [306 N (31 kg)/25 mm].

2.3 FIELD APPLIED JACKETS

- A. Fire retardant Information: This product does not contain polybrominated diphenyl ethers (PBDE) such as: Penta-BDE, Octa-BDE or Deca-BDE.
- B. PVC: Proto Corporation 25/50 or Indoor/Outdoor, UV-resistant fittings, jacketing and accessories, white or colored. Fitting cover system consists of pre-molded, high-impact PVC materials with fiber glass inserts. Fiber glass insert has a thermal conductivity (k value) of 0.26 at 75° F (0.037 at 24°C) mean temperature. Closures: stainless steel tacks, matching PVC tape, or PVC adhesive per manufacturer's recommendations.
- C. Metal: Aluminum, 0.016-inch (0.406 mm) thick or Stainless Steel, 0.010-inch (0.254 mm) thick in smooth, corrugated, or embossed finish with factory-applied moisture barrier. Overlap shall be 2-inch (50 mm) minimum. Fittings shall be die-shaped with factory-applied moisture barrier.
- D. Laminated Self-Adhesive Water and Weather Seals: permanent acrylic self-adhesive system; weather resistant, high puncture and tear resistance; meeting or exceeding requirements of UL 723; applied in strict accordance with manufacturers' recommendations.

2.4 OUTDOOR DUCTWORK

- A. Aluminum Jacket: 0.016-inch (0.406 mm) thick in smooth, corrugated, or embossed finish with factory applied moisture barrier. Overlap shall be 2-inch (50 mm) minimum. PVC Jacket: Proto Corporation Indoor/Outdoor, UV resistant, white. Closure shall be solvent weld adhesive or per manufacturers' recommendations.
- B. Laminated Self-Adhesive Water and Weather Seals: applied per manufacturers' recommendations.
- C. Either ductwork or insulation shall be installed so as to shed water and not allow standing water.

PART 3 — EXECUTION

3.1 EXAMINATION

- A. Verify that all piping, ductwork, and equipment are tested and approved prior to insulation installation.
- B. Verify that all surfaces are clean, dry and without foreign material before applying insulation materials.

3.2 GENERAL INSULATION REQUIREMENTS

- A. All materials shall be installed by skilled labor regularly engaged in this type of work. All materials shall be installed in strict accordance with manufacturer's recommendations, building codes, and industry standards.
- B. Locate insulation and cover seams in the least visible location. All surface finishes shall be extended in such a manner as to protect all raw edges, ends and surfaces of insulation.

- C. On cold surfaces where a vapor seal must be maintained, insulation shall be applied with a continuous, unbroken moisture and vapor retarder. All hangers, supports, anchors, or other projections secured to cold surfaces shall be insulated and vapor sealed to prevent condensation.
 - D. All pipe insulation shall be continuous through walls, ceiling or floor openings or sleeves except where firestop or firesafing materials are required.
 - E. Install multiple layers of insulation with longitudinal and circumferential joints staggered.
- 3.3 PIPING INSULATION: 1000° PIPE INSULATION AND REDI-KLAD® 1000° PIPE INSULATION
- A. Locate all seams in the least visible location.
 - B. Insulation installed on piping operating below ambient temperatures must have a continuous vapor retarder. All joints, seams and fittings must be sealed. On systems operating above ambient, the butt joints should not be sealed.
 - C. On high-temperature piping, above 500°F (260°C), insulation shall be applied using double-layer with staggered joints. When double layering, the inner layer should not be jacketed. All joints and ends must be firmly butted and secured with appropriate securement material.
 - D. Metal shields shall be installed between hangers or supports and the piping insulation. Rigid insulation inserts shall be installed as required between the pipe and the insulation shields. Inserts shall be of equal thickness to the adjacent insulation and shall be vapor sealed as required. Insulation inserts shall be no less than the following lengths:

1½" to 2½" IPS	10" long
3" to 6" IPS	12" long
8" to 10" IPS	16" long
12" and over IPS	22" long
 - E. For piping exposed in mechanical rooms or high traffic areas, insulation shall be protected from abuse by the use of appropriate thickness of PVC jacketing, metal jacketing or laminated self-adhesive water and weather seals.
 - F. For piping exposed to the elements install Redi-Klad® with 4" butt strips and self sealing lap or a jacketing that shall be UV resistant PVC with a minimum thickness of 0.020 inches, or 0.016 inches (0.406) thick aluminum with factory applied moisture barrier or 0.010 inches (0.254mm) thick stainless steel with a factory applied moisture barrier. Fitting covers shall be of similar materials. The insulation and jacketing shall be held firmly in place with a friction type Z lock or a minimum 2" overlap joint. For systems operating below ambient, all PVC joints shall be sealed completely along the longitudinal and circumferential seams and installed so as to shed water. When required, all PVC circumferential joints shall be sealed by use of preformed butt strips; minimum 2" wide or a minimum 2" overlap. Butt strips shall overlap the adjacent jacketing a minimum ½ inch and be completely weather sealed. PVC Jacketing shall be limited to a maximum 20-inch OD of the insulation when exposed to direct sunlight. For systems operating above ambient, circumferential joints should overlap a minimum of 2" and not be sealed. Insulation thickness for piping covered by PVC Jacketing shall be such that the surface temperature of the PVC does not exceed 125°F (52°C).
 - G. Insulate valves, balancing valves and other devices requiring access with removable covers. Covers shall have a minimum k-factor of .26 using fiberglass blanket. Flame and smoke spread shall be 25/50 per ASTM E-84. Covers shall be completely overlapping and completely cover the adjacent insulation with seams and butt ends secure.
 - H. Cold Piping Installation / High Abuse Systems
 1. On systems operating below freezing or systems operating in high abuse areas install Redi-Klad® with 4" butt strips and self sealing lap; or the ASJ+ jacket shall be protected with a PVC vapor retarding outer jacket. In addition, exposed ends of the insulation shall be sealed with a vapor retarder mastic installed per the manufacturer's recommendations. Vapor stops, vapor retarder mastic applied in the insulation butt joint from the vapor retarder jacket to the pipe, shall be applied at every fourth pipe section joint and at each fitting to isolate any water incursion or transmission.
 2. On systems operating below ambient and in conditions of Design RH of 90% and above, it is recommended that the same guidelines be followed as listed above for below freezing applications.

3.4 PIPING INSULATION: PIPE & TANK INSULATION AND KWIKFLEX® PIPE & TANK INSULATION

- A. Apply on clean, dry surfaces.
- B. Cut to appropriate length using manufacturers' stretchout guide for the specific pipe size. Add an additional 2 inches (51 mm) to 4 inches (102 mm) for a staple flap.
- C. Wrap around the pipe to ensure proper fit. Staple the lap on 3 inch (76 mm) centers with outward clinching staples.
- D. On systems operating below ambient, appropriate UL approved vapor retarder shall be applied to all longitudinal and circumferential joints.
- E. For piping exposed to the elements, jacketing shall be UV resistant PVC with a minimum thickness of 0.020 inches, or 0.016 inches (0.406) thick aluminum with factory applied moisture barrier or 0.010 inches (0.254mm) thick stainless steel with a factory applied moisture barrier or laminated self-adhesive water and weather seals. Fitting covers shall be of similar materials. The insulation and jacketing shall be held firmly in place with a friction type Z lock or a minimum 2" overlap joint. For systems operating below ambient, all PVC joints shall be sealed completely along the longitudinal and circumferential seams and installed so as to shed water. When required, all PVC circumferential joints shall be sealed by use of preformed butt strips; minimum 2" wide or a minimum 2" overlap. Butt strips shall overlap the adjacent jacketing a minimum ½ inch and be completely weather sealed. PVC Jacketing shall be limited to a maximum 20-inch OD of the insulation when exposed to direct sunlight. For systems operating above ambient, circumferential joints should overlap a minimum of 2" and not be sealed. Insulation thickness for piping covered by PVC Jacketing shall be such that the surface temperature of the PVC does not exceed 125°F (52°C).
- F. On below ambient piping, vapor retarder mastic shall be applied to the ends at every fourth section and at each fitting before taping.

3.5 EQUIPMENT INSULATION-FIBER GLASS

- A. Apply insulation to the equipment surface with joints firmly butted and as close as possible to the equipment surface. Insulation shall be secured as required with mechanical fasteners or banding material. Fasteners shall be located a maximum of 3" from each edge and spaced no greater than 12" on center.
- B. For below ambient systems, vapor retarder jacketing shall overlap a minimum of 2" at all seams and be sealed with appropriate pressure-sensitive tape or mastic. All penetrations and facing damage shall be covered with a minimum 2" overlap of tape or mastic.
- C. Equipment insulation exposed to the elements shall be finished with minimum 0.030-inch thick, outdoor, weather resistant PVC; laminated self-adhesive water based weatherproof mastic and glass cloth; or metal. All longitudinal joints shall be positioned so as to shed water; with a minimum 3" overlap, and completely weather sealed. Laminated systems shall be applied per manufacturer's recommendations.
- D. For high-temperature applications, insulation may either be mounted in direct contact with the hot surface, in H-bar configuration, or pre-fabricated panel systems mounted away from the operating surface. When installing H-Bar or panel systems which are mounted away from the operating surface, convection stops shall be installed at a maximum of 8 feet along the vertical surfaces. Insulation may be applied over welded pins or studs up to ½" in diameter. Insulation shall be held in place using mesh reinforcement or steel bands. Insulation shall not be compressed beyond a maximum of 1/8 inch at any point. Pins and studs shall be spaced a maximum of 4" from each edge and no greater than 16" on center. For temperatures above 500°F (260°C) and design thicknesses over 3", insulation shall be applied using double-layer with staggered joints. Finish shall be minimum 0.020-inch thick PVC jacketing, insulating cement with canvas, glass cloth with mastic, or metal as specified on the drawings.
- E. For Equipment insulation exposed in mechanical rooms or subject to mechanical abuse, finish with minimum 0.020 inch thick PVC Jacketing or metal or laminated self-adhesive water and weather seals. All other insulation shall be finished as appropriate for the location and service or as specified on the drawings.

3.6 INTERNAL DUCT LINING

- A. Duct Lining shall be applied in strict accordance with the latest edition of SMACNA's "HVAC Duct Construction Standard Metal & Flexible" and NAIMA's "Fibrous Glass Duct Liner Standard".
- B. Length of mechanical fasteners shall be selected in accordance with the manufacturer's recommendation as listed on each product. Mechanical fasteners shall be installed perpendicular to the duct surface, and in no instance shall the pin compress the liner more than 1/8" relative to the nominal thickness of the insulation.
- C. All exposed edges of the duct liner shall be coated with the factory applied edge coating or an adhesive which conforms to ASTM C 916.
- D. When duct lining is applied with an adhesive, the adhesive shall be applied to the sheet metal with a 90% minimum coverage. All exposed duct liner edges not coated by the manufacturer shall be coated with the same adhesive. All rips and tears shall be repaired using this same adhesive.
- E. Transverse joints shall be firmly butted with no gaps and coated with adhesive. Longitudinal corner joints shall be overlapped and compressed.
- F. When air velocities are 4000 to 6000 FPM, metal nosing shall be applied to all upstream transverse edges to additionally secure the insulation.

3.7 FLEXIBLE FIBER GLASS BLANKET

- A. Install Duct Wrap using manufacturer's stretch-out tables to obtain specified R-value using a maximum compression of 25%.
- B. Installed R-value shall be per ASHRAE 90.1; UCC Code; or other design criteria.
- C. Firmly butt all joints.
- D. The longitudinal seam of the vapor retarder must be overlapped a minimum of 2 inches. A 2-inch tab is provided on Knauf Insulation Friendly Feel[®] Duct Wrap for the circumferential seam.
- E. Where vapor retarder performance is required, all penetrations and damage to the facing shall be repaired using pressure-sensitive tape matching the facing, or mastic prior to system startup. Pressure-sensitive tapes shall be a minimum 3 inches wide and shall be applied with moving pressure using a squeegee or other appropriate sealing tool. Closure shall have a 25/50 Flame Spread/Smoke Developed Rating per UL 723.
- F. Duct Wrap shall be additionally secured to the bottom of rectangular ductwork over 24 inches wide using mechanical fasteners on 18-inch centers. Care should be exercised to avoid over-compression of the insulation during installation. Unfaced Duct Wrap shall be overlapped a minimum of 2 inches and fastened using 4-inch to 6-inch nails or skewers spaced 4 inches apart, or secured with a wire/banding system. Care should be exercised to avoid damage to the Duct Wrap.

3.8 ROUND DUCTWORK - PIPE & TANK INSULATION AND KWIKFLEX[®] PIPE & TANK INSULATION

- A. Apply on clean, dry surfaces.
- B. Cut to appropriate length using manufacturers' stretch-out guide for the specific duct size. Add an additional 2 inches (51 mm) to 4 inches (102 mm) for a staple flap.
- C. Wrap around the duct to ensure proper fit. Staple the lap on 3 inch (76 mm) centers with outward clinching staples.
- D. Ends shall be firmly butted and secured with matching butt strip material at each joint.
- E. On below ambient ductwork, appropriate UL approved vapor retarder shall be applied to all longitudinal and circumferential joints before application of butt strip material.

3.9 FIBER GLASS DUCTWORK

- A. Ductwork shall be fabricated and installed in strict accordance with the latest edition of NAIMA's "Fibrous Glass Duct Construction Standard" and manufacturer's recommendations.
- B. Closure system shall be UL 181 tested and listed: Pressure-Sensitive Aluminum Foil Tapes: UL 181 Part I (marked UL 181 A-P). Heat Sealable Closures: UL 181 Part II (marked UL 181 A-H). Mastics: UL 181 Part III (marked UL 181 A-M) with 3-inch wide glass fabric.
- C. All longitudinal and transverse joints having a 1½" staple flap shall be secured with outward-clinching staples on approximate 2-inch centers and sealed with approved closure system.

- D. Transverse shiplap joints not having staples flaps, or transverse butt joints shall be secured with 8-inch long cross tabs running perpendicular to the joint seam on 12-inch centers. Cross tabs shall be made from an approved closure tape. The seam of the joint shall then be sealed with an approved closure system.
 - E. Duct sections shall be additionally reinforced per NAIMA's and manufacturer's recommendations when necessary. Reinforcement is dependent on duct width and operating pressure.
 - F. Ductwork shall be suspended and supported as required on straight runs, at all turns, and at transitions to maintain proper alignment. Hangers and supports shall be in strict accordance with NAIMA's and manufacturer's recommendations.
- 3.10 INSULATION SCHEDULES
- A. ASHRAE 90.1 – 2010 Requirements, Pipe Insulation
 - 1. The minimum insulation thickness based upon ASHRAE 90.1 **do not necessarily represent the Economic Thickness of Insulation or the thickness required for proper condensation control**. Rather, they serve as minimum recommendations for commercial applications. For recommended Economic Thickness and System Design, install according to NAIMA 3E Plus or as specified.

Minimum Pipe Insulation Thickness ^a							
Fluid Design Operating Temp. Range (° F.)	Insulation Conductivity		Nominal Pipe or Tube Size (in.)				
	Conductivity Btu-in./[hr·ft ² ·°F)	Mean Rating Temp. °F.	<1	1 to < 1½	1½ to < 4	4 to <8	≥8
Heating Hot Water Systems (Steam, Steam Condensate, Hot Water Heating and Domestic Water Systems)^{b,c}							
>350	0.32 – 0.34	250	4.5	5.0	5.0	5.0	5.0
251 – 350	0.29 – 0.31	200	3.0	4.0	4.5	4.5	4.5
201 – 250	0.27 – 0.30	150	2.5	2.5	2.5	3.0	3.0
141 – 200	0.25 – 0.29	125	1.5	1.5	2.0	2.0	2.0
105 – 140	0.22 – 0.28	100	1.0	1.0	1.5	1.5	1.5
Cooling Systems (Chilled Water, Brine, and Refrigerant) ^d							
40 – 60	0.21 – 0.27	75	0.5	0.5	1.0	1.0	1.0
<40	0.20 – 0.26	50	0.5	1.0	1.0	1.0	1.5

^a For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows: $T = r\{(1 + t/r)^{K/k} - 1\}$. Where T = minimum insulation thickness (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature {Btu·in.(hr·ft²·°F)}; and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.

^b These thicknesses are based on energy *efficiency* considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.

^c For piping smaller than 1.5" and located in partitions within conditioned spaces, reduction of these thicknesses by 1" shall be permitted (before thickness adjustment required in footnote a) but not to thicknesses below 1".

^d These thicknesses are based on energy *efficiency* considerations only. **Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.**

^e The table is based on steel pipe. Non-metallic pipes scheduled 80 thickness or less shall use the table values. For other non-metallic pipes having thermal resistance greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown on the table.

B. NECESSARY PIPE INSULATION THICKNESS TO PREVENT CONDENSATION:

Jacket: ASJ+ ($\epsilon = 0.9$) Wind Speed = 0 mph Ambient Temperature = 80°F

Pipe Size	Relative Humidity & Operating Temperature					Relative Humidity & Operating Temperature					Relative Humidity & Operating Temperature				
	70% RH					80% RH					90% RH				
	35°F	40°F	45°F	50°F	55°F	35°F	40°F	45°F	50°F	55°F	35°F	40°F	45°F	50°F	55°F
0.5	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	0.5"	0.5"	1.5"	1.5"	1.5"	1.0"	1.0"
1	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	0.5"	0.5"	1.5"	1.5"	1.5"	1.5"	1.0"
1.5	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	0.5"	2.0"	2.0"	1.5"	1.5"	1.5"
2	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	0.5"	2.0"	2.0"	1.5"	1.5"	1.5"
4	1.0"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	0.5"	2.0"	2.0"	2.0"	1.5"	1.5"
6	1.0"	0.5"	0.5"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	0.5"	2.5"	2.5"	2.0"	2.0"	1.5"
8	1.0"	0.5"	0.5"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	0.5"	2.5"	2.5"	2.0"	2.0"	1.5"
10	1.0"	0.5"	0.5"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	0.5"	2.5"	2.5"	2.0"	2.0"	1.5"
12	1.0"	1.0"	1.0"	1.0"	0.5"	1.5"	1.0"	1.0"	1.0"	1.0"	2.5"	2.5"	2.0"	2.0"	1.5"

Jacket: ASJ+ ($\epsilon = 0.9$) Wind Speed = 0 mph Ambient Temperature = 90°F

Pipe Size	Relative Humidity & Operating Temperature					Relative Humidity & Operating Temperature					Relative Humidity & Operating Temperature				
	70% RH					80% RH					90% RH				
	35°F	40°F	45°F	50°F	55°F	35°F	40°F	45°F	50°F	55°F	35°F	40°F	45°F	50°F	55°F
0.5	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	0.5"	0.5"	2.0"	1.5"	1.5"	1.0"	1.0"
1	0.5"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	0.5"	2.0"	2.0"	2.0"	1.5"	1.5"
1.5	1.0"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	1.0"	2.0"	2.0"	2.0"	2.0"	1.5"
2	1.0"	0.5"	0.5"	0.5"	0.5"	1.0"	1.0"	1.0"	1.0"	1.0"	2.5"	2.0"	2.0"	2.0"	1.5"
4	1.0"	0.5"	0.5"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	1.0"	3.0"	2.5"	2.5"	2.0"	2.0"
6	1.0"	1.0"	0.5"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	1.0"	3.0"	3.0"	2.5"	2.5"	2.0"
8	1.0"	1.0"	1.0"	0.5"	0.5"	1.5"	1.0"	1.0"	1.0"	1.0"	3.0"	3.0"	2.5"	2.5"	2.0"
10	1.0"	1.0"	1.0"	0.5"	0.5"	1.5"	1.5"	1.0"	1.0"	1.0"	3.5"	3.0"	2.5"	2.5"	2.0"
12	1.0"	1.0"	1.0"	1.0"	0.5"	1.5"	1.5"	1.0"	1.0"	1.0"	3.5"	3.0"	2.5"	2.5"	2.0"

C. ASHRAE 90.1 – 2010 REQUIREMENTS – DUCT INSULATION

Minimum Duct Insulation R-Value ^a, Cooling and Heating Only Supply Ducts and Return Ducts

Climate Zone Buried	Duct Location					
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling	Unvented Attic with Roof Insulation ^a	Unconditioned Space ^b	Indirectly Conditioned Space ^c
	Heating – Only Ducts					
1,2	none	none	none	none	none	none
3	R – 3.5	none	none	none	none	none
4	R – 3.5	none	none	none	none	none
5	R – 6.0	R – 3.5	none	none	none	none
6	R – 6.0	R – 6.0	R – 3.5	none	none	none
7	R – 8.0	R – 6.0	R – 6.0	none	R – 3.5	none
8	R – 8.0	R – 8.0	R – 6.0	none	R – 6.0	none
Cooling – Only Ducts						
1	R – 6.0	R – 6.0	R – 8.0	R – 3.5	R – 3.5	none
2	R – 6.0	R – 6.0	R – 6.0	R – 3.5	R – 3.5	none
3	R – 6.0	R – 6.0	R – 6.0	R – 3.5	R – 1.9	none
4	R – 3.5	R – 3.5	R – 6.0	R – 1.9	R – 1.9	none
5,6	R – 3.5	R – 1.9	R – 3.5	R – 1.9	R – 1.9	none
7,8	R – 1.9	R – 1.9	R – 1.9	R – 1.9	R – 1.9	none
Return Ducts						
1 to 8	R – 3.5	R – 3.5	R – 3.5	none	none	none

^a Insulation R – values, measured in (hr· ft²· °F)/Btu, are for the insulation as installed and do not include film resistance. The

required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior

walls are used as plenum walls, wall insulation shall be required by the most restrictive condition of Section 6.4.4.2 or Section 5.

Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a Mean temperature of 75° F at the installed thickness.

^b Includes crawlspaces, both ventilated and non-ventilated.

^c Includes return air plenum with or without exposed roofs above.

C. (cont.) ASHRAE 90.1 – 2010 REQUIREMENTS – DUCT INSULATION

Minimum Duct Insulation R-Value^a, Combined Heating and Cooling Supply Ducts and Return Ducts

Climate Zone	Duct Location					
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling	Unvented Attic with Roof Insulation ^a	Unconditioned Space ^b	Indirectly Conditioned Space ^c
Supply Ducts						
1	R – 6.0	R – 6.0	R – 8.0	R – 3.5	R – 3.5	none
2	R – 6.0	R – 6.0	R – 6.0	R – 3.5	R – 3.5	none
3	R – 6.0	R – 6.0	R – 6.0	R – 3.5	R – 3.5	none
4	R – 6.0	R – 6.0	R – 6.0	R – 3.5	R – 3.5	none
5	R – 6.0	R – 6.0	R – 6.0	R – 1.9	R – 3.5	none
6	R – 8.0	R – 6.0	R – 6.0	R – 1.9	R – 3.5	none
7	R – 8.0	R – 6.0	R – 6.0	R – 1.9	R – 3.5	none
8	R – 8.0	R – 8.0	R – 8.0	R – 1.9	R – 6.0	none
Return Ducts						
1 to 8	R – 3.5	R – 3.5	R – 3.5	none	none	none

^a Insulation R – values, measured in (hr· ft²· °F)/Btu, are for the insulation as installed and do not include film resistance. The

required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior

walls are used as plenum walls, wall insulation shall be required by the most restrictive condition of Section 6.4.4.2 or Section 5.

Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a Mean temperature of 75° F at the installed thickness.

^b Includes crawlspaces, both ventilated and non-ventilated.

^c Includes return air plenum with or without exposed roofs above.

D. IECC CODE REQUIREMENTS

503.2.7 Duct and plenum insulation and sealing.

All supply and return air ducts and plenums shall be insulated with a minimum of R-5 insulation when located in unconditioned spaces and a minimum of R-8 insulation when located outside the building. When located within a building envelope assembly, the duct or plenum shall be separated from the building exterior or unconditioned or exempt spaces by a minimum of R-8 insulation.

Exceptions:

1. When located within equipment.
2. When the design temperature difference between the interior and exterior of the duct or plenum does not exceed 15°F (8°C).

All ducts, air handlers and filter boxes shall be sealed. Joints and seams shall comply with Section 603.9 of the *International Mechanical Code*.

Systems to Achieve Required R-values For ASHRAE 90.1 and IECC

R – 5:

1. Air Duct Board – 1-1/2" thick (R 6.5)
2. Sheet metal ductwork with .75 PCF 2" Duct Wrap (R 5.6 @ 25% compression)
3. Sheet metal ductwork with 1.5 PCF 1-1/2" thick rotary* Duct Liner (R 6.0)

R – 8:

1. Air Duct Board – 2" thick (R 8.7)
2. Sheet metal ductwork with .75 PCF 3" thick Duct Wrap (R 8.4 @ 25% compression)
3. Sheet metal ductwork with 1.5 PCF 2" thick rotary* Duct Liner (R 8.0)

* Textile Duct Liner may not achieve the required R-value.

E. MINIMUM DUCT WRAP INSULATION (INSTALLED) TO PREVENT CONDENSATION

Jacket: Aged Aluminum Foil or Galvanized Sheet Metal ($\epsilon = 0.2$) Wind Speed = 0 mph

Operating Temperature: 45°F					
Rel. Humidity	Ambient Temperature				
	70°F	80°F	90°F	100°F	110°F
60%	2.2	3.3	4.3	4.3	5.4
70%	3.3	5.4	6.5	7.6	**
80%	7.0	**	**	**	**

Operating Temperature: 55°F					
Rel. Humidity	Ambient Temperature				
	70°F	80°F	90°F	100°F	110°F
60%	1.1	2.2	3.3	3.3	4.3
70%	1.1	3.3	4.3	6.5	6.5
80%	3.3	6.5	**	**	**

Operating Temperature: 65°F					
Rel. Humidity	Ambient Temperature				
	70°F	80°F	90°F	100°F	110°F
60%	1.1	1.1	2.2	3.3	4.3
70%	1.1	1.1	3.3	5.4	6.5
80%	2.2	3.3	6.5	**	**
90%	6.5	**	**	**	**

** Necessary R-value is greater than one typically supplied in duct wrap. Please consult manufacturer.

F. FIBERGLASS DUCTWORK - REINFORCEMENT SCHEDULES

1. Tie Rod System (Positive Pressure Only)

Positive Static Pressure	Inside Duct Dimension (inches)	TYPE 475 BOARD			TYPE 800 BOARD		
		No. Rods Across Dimension	Maximum Longitudinal Spacing	No. Rods per 4 ft. Section	No. Rods Across Dimension	Maximum Longitudinal Spacing	No. Rods per 4 ft. Section
0 thru ½" W.G.	0-36	*			*		
	37-42	2	24"	4	2	48"	2
	43-48	2	24"	4	2	48"	2
	49-60	3	24"	6	3	48"	3
	61-64	3	24"	6	3	24"	6
	65-80	4	24"	8	4	24"	8
	81-96	5	24"	10	5	24"	10
Over ½" Thru 1" W.G.	0-24	*			*		
	25-30	1	24"	2	1	48"	1
	31-32	1	24"	2	1	24"	2
	33-36	2	24"	4	2	24"	4
	37-48	2	24"	4	2	24"	4
	49-64	3	24"	6	3	24"	6
	65-80	4	24"	8	4	24"	8
81-96	5	24"	10	5	24"	10	
Over 1" Thru 2" W.G.	0-14	*			*		
	15-18	1	24"	2	*		
	19-24	1	24"	2	1	24"	2
	25-32	1	16"	3	1	24"	2
	33-48	2	16"	6	2	24"	4
	49-60	3	16"	9	3	24"	6
	61-64	3	16"	9	3	16"	9
	65-80	4	16"	12	4	16"	12
81-96	5	16"	15	5	16"	15	

* Straight ducts of these dimensions do not require reinforcement. However, some fittings of these dimensions may require reinforcement.

NOTES:

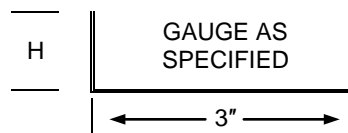
1. Tie rods and washers must be no more than 16" on center across duct dimension.
2. Ducts of 48" width and over require use of anti-sag devices.
3. For duct dimensions over 96", maintain tie rod spacing on 16-inch center across the duct dimension following longitudinal spacing for the design pressure.
4. If dimensions require, tie rods run in both horizontal and vertical directions.

2. Channel System (Positive and Negative Pressure)

Static Pressure		Max. Inside Duct Dimension (inches)	TYPE 475 BOARD			TYPE 800 BOARD		
			Maximum Longitudinal Spacing	Channel Gauge	H Dimension (see note)	Maximum Longitudinal Spacing	Channel Gauge	H Dimension (see note)
0 thru ½" W.G.	negative	0-30	*			*		
		31-36	24"	22	1"	48"	22	1"
	positive	0-36	*			*		
0 thru ½" W.G.	positive or negative	37-42	24"	22	1"	48"	22	1"
		43-48	24"	22	1"	48"	22	1"
		49-60	24"	22	1"	48"	22	1½"
		61-72	24"	22	1"	24"	22	1"
		73-84	24"	22	1"	24"	22	1"
		85-96	24"	22	1¼"	24"	22	1"
Over ½" Thru 1" W.G.	positive or negative	0-24	*			*		
		25-30	24"	22	1"	48"	22	1"
		31-36	24"	22	1"	24"	22	1"
		37-42	24"	22	1"	24"	22	1"
		43-48	24"	22	1"	24"	22	1"
		49-60	24"	22	1"	24"	22	1"
		61-72	24"	18	1"	24"	18	1"
		73-84	24"	18	1¼"	24"	18	1¼"
		85-96	24"	18	1¼"	24"	18	1¼"
Over 1" Thru 2" W.G.	positive or negative	0-15	*			*		
		16-18	24"	22	1"	*		
		19-24	24"	22	1"	24"	22	1"
		25-36	16"	22	1"	24"	22	1"
		37-48	16"	22	1"	24"	22	1¼"
		49-60	16"	22	1"	24"	22	1¼"
		61-72	16"	18	1"	16"	18	1"
		73-84	16"	18	1¼"	16"	18	1¼"
		85-96	16"	18	1½"	16"	18	1½"

* Straight ducts of these dimensions do not require reinforcement. However, some fittings of these dimensions may require reinforcement.

NOTES: 1. Ducts of 48" width and over require use of anti-sag devices.



G. FIBERGLASS DUCTWORK - MAXIMUM HANGER SPACING

Duct Size, Inches	Maximum Hanger Spacing
48" wide or greater	4 ft.
Less than 48" wide and less than 12" high	6 ft.
Width between 24" & 48" and greater than 24" high	6 ft.
Less than 48" wide and height between 12" & 24"	8 ft.
Width 24" or less and height greater than 12"	8 ft.

END OF SECTION 230700