KNAUF INSULATION

Guide Specifications | K-GS-1 11-07

Plumbing Insulation
Section 220700

HVAC Insulation
Section 230700

Plumbing Insulation— Section 220700

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 VentureClad
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
3. Definitions
   a. Thermal Conductivity (k Value) : BTU-in./(hr•ft²•°F)
   b. Greenguard: Greenguard Environmental Institute, independent testing of products for emissions of respirable particles and Volatile Organic Compounds (VOCs), including formaldehyde and other specific product-related pollutants. Provides independent, third-party certification of IAQ performance. 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
   g. SSL: Self-Sealing Lap
   h. FSK: Foil-Scrim-Kraft; jacketing
   i. PSK: Poly-Scrim-Kraft; jacketing
   j. PVC: Polyvinyl Chloride
   k. FRP: Fiberglass Reinforced Plastic

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 as required.

1.4 Quality Assurance

A. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products per ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes and cement material containers 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. Maintain ambient conditions required by manufacturers of tapes, adhesives, mastics, cements, and insulation materials.

C. Follow manufacturer's recommended handling practices.

D. Supply fiberglass products that assure excellent IAQ (Indoor Air Quality) performance through Greenguard Certification whenever possible.

E. Fiber Glass and Mold: Fiber glass insulation is not a food source for mold growth. However, mold can grow on almost any material when it becomes wet and contaminated with organic materials.

Carefully inspect any insulation that has been exposed to water. If it shows any sign of mold growth it must be discarded. If the material is wet but shows no sign of mold, it should be dried rapidly and thoroughly. If it shows signs of facing degradation from wetting, it should be replaced. 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, 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 equal.

E. Glass Fiber: Knauf 1000° Pipe Insulation meeting ASTM C 547, ASTM C 585, and ASTM C 795; rigid, molded, noncombustible. 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, secured with self-sealing longitudinal laps and butt strips.

F. Glass Fiber: Knauf Pipe & Tank Insulation; 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" (51 mm) thickness per ASTM C 165. Vapor Retarder Jacket: ASJ conforming to ASTM C 1136 Type II.

G. Glass Fiber: Knauf KwikFlex; 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" (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.

H. Fitting Insulation: Pre-formed fiberglass, preformed perlite, mitered fiberglass, mitered perlite or calcium silicate in lieu of PVC systems. These fittings shall be further protected by field-applied fitting covers or metal fittings as necessary.

2.2 Factory Applied Jackets

A. ASJ/SSL: All service jacket with self-sealing lap. White-kraft paper bonded to aluminum foil and reinforced with glass fibers; conforming to ASTM C 1136 Type 1; 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.

2.3 Field Applied Jackets

A. 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.

B. Metal: Aluminum, 0.016" (0.406 mm) thick or Stainless Steel, 0.010" (0.254 mm) thick in smooth, corrugated, or embossed finish with factory-applied moisture barrier. Overlap shall be 2" (50 mm) minimum. Fittings shall be die-shaped with factory-applied moisture barrier.

C. 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 retarder must be maintained, insulation shall be applied with a continuous, unbroken moisture and vapor seal. 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

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.

C. All ends must be firmly butted and secured with appropriate butt-strip material. On high-temperature piping, double layering with staggered joints may be appropriate. When double layering, the inner layer should not be jacketed.

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 or metal jacketing.

F. For piping exposed to the elements, jacketing shall be UV resistant PVC with a minimum thickness of 0.020", or 0.016" thick aluminum or 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. All joints shall be sealed completely along the longitudinal seam and installed so as to shed water. All 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" and be completely weather sealed. PVC Jacketing shall be limited to a maximum 20" OD of the insulation when exposed to direct sunlight. A 6" to 10" unsealed slide joint shall be installed every 25 to 30 lineal feet for the thermal expansion of the pipe and jacketing. Where distance between fittings exceeds 8 lineal feet, an unsealed slide joint of 6" to 10" shall be installed. 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. Cold Piping Insulation

1. On below freezing applications and in high abuse areas, 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 seals at butt joints shall be applied at every fourth pipe section joint and at each fitting to isolate any water incursion.
2. On chilled water systems operating 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™

A. Apply on clean, dry surfaces.

B. Cut to appropriate length using manufacturers' stretchout guide to for the specific pipe size. Add an additional 2" (51 mm) to 4" (102 mm) for a staple flap.

C. Wrap around the pipe to ensure proper fit. Staple the lap on 3" (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 piping, appropriate UL approved vapor retarder shall be applied to all longitudinal and circumferential joints before application of butt strip material.

3.5 Equipment Insulation—Fiber glass

A. Apply insulation with joints firmly butted as close as possible to the equipment surface. Insulation shall be secured as required with adhesive, 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. Vapor retarders shall overlap a minimum of 2" at all seams and be sealed with appropriate pressure-sensitive tape or mastic. All penetrations, facing damage, and mechanical fasteners 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" thick outdoor weatherable PVC, laminated self-adhesive water and weather seal, weatherproof mastic and glass cloth, or metal. All joints shall be positioned so as to shed water; with a minimum 3" overlap, and completely weather sealed. Laminated system shall be applied per manufacturer's recommendations.

D. For high-temperature applications, insulation may be mounted in contact with the hot surface, in H-bar configuration, or in panels mounted away from the operating surface. 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 5% 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 550°F (288°C) and design thicknesses over 3", insulation shall be applied double-layer with staggered joints. Finish shall be minimum 0.020" 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" thick PVC Jacketing or metal. All other insulation shall be finished as appropriate for the location and service or as specified on the drawings.

3.6 Schedules

A. ASHRAE 90.1-1989 Requirements, Pipe Insulation

1. The minimum insulation thicknesses 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 Systems Design, install according to NAIMA ETI program (3E Plus) or as specified.

Minimum Pipe Insulation (in.)
(To meet ASHRAE 90.1 Requirements)

Conductivity			Nominal Pipe Diameter (in.)					
Fluid Design Operating Temperature Range, °F	Conductivity Range Btu-in./(hr•ft²•°F)	Mean Temperature Rating, °F	Runouts[a] up to 2	1 and less	1¼ to 2	2½ to 4	5 & 6	8 & up
Heating Systems (Steam, Steam Condensate and Hot Water)								
Above 350	.32-.34	250	1½	2½	2½	3	3½	3½
251-350	.29-.31	200	1½	2	2½	2½	3½	3½
201-250	.27-.30	150	1	1½	1½	2	2	3½
141-200	.25-.29	125	½	1½	1½	1½	1½	1½
105-140	.24-.28	100	½	1	1	1	1½	1½
Domestic and Service Hot Water Systems[b]								
105 and Greater	.24-.28	100	½	1	1	1 ½	1 ½	1 ½
Cooling Systems (Chilled Water, Brine, Refrigerant)[c]								
40-55	.23-.27	75	½	½	¾	1	1	1
Below 40	.23-.27	75	1	1	1½	1½	1½	1½

[a] For minimum thicknesses of insulations not in the conductivity range, use:

$$T = PR[(1 + t/PR)^{K/k} - 1]$$

where

T is minimum insulation thickness for material with conductivity K, in.;
PR is pipe actual outside radius, in.;
t is insulation thickness from above table, in.;
K is conductivity of insulation at the mean temperature indicated in above table for the applicable fluid temperature range, Btu□in./(h□ft²□°F);
k is the lower value of the conductivity range listed in the above table for the applicable fluid temperature range, Btu□in./(h□ft²□°F).

[b] Runouts to individual terminal units not exceeding 12 ft. in length.
[c] Applies to recirculating sections of service or domestic hot water systems and first 8 ft. from storage tank for non-recirculating systems.
[d] These thicknesses are based on energy efficiency considerations only. The required minimum thickness does not consider water vapor transmission and condensation. Additional insulation, vapor retarders, or both, may be required to limit water vapor transmission and condensation.

B.

Necessary Pipe Insulation Thickness to Prevent Surface Condensation
Jacket: ASJ (= 0.9) Wind Speed = 0 mph

Ambient Temperature = 80ºF
Relative Humidity & Operating Temperature

Pipe Size	70% RH					80% RH					90% RH				
	35ºF	40ºF	45ºF	50ºF	55ºF	35ºF	40ºF	45ºF	50ºF	55ºF	35ºF	40ºF	45ºF	50ºF	55ºF
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"	0.5"	1.0"	2.5"	2.5"	2.0"	2.0"	1.5"

Ambient Temperature = 90ºF
Relative Humidity & Operating Temperature

Pipe Size	70% RH					80% RH					90% RH				
	35ºF	40ºF	45ºF	50ºF	55ºF	35ºF	40ºF	45ºF	50ºF	55ºF	35ºF	40ºF	45ºF	50ºF	55ºF
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. EQUIPMENT INSULATION SCHEDULE:

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

END OF PLUMBING INSULATION—SECTION 220700

HVAC Insulation— Section 230700

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
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 National Association, Inc. (SMACNA)
   f. Underwriter's Laboratories (UL)
   g. Greenguard
3. Definitions
   a. Thermal conductivity (k Value): BTU-in./(hr•ft²•°F)
   b. Greenguard: Greenguard Environmental Institute, independent testing of products for emissions of respirable particles and Volatile Organic Compounds (VOCs), including formaldehyde and other specific product-related pollutants. Provides independent, third-party certification of IAQ performance. 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
   g. SSL: Self-Sealing Lap
   h. FSK: Foil-Scrim-Kraft; jacketing
   i. PSK: Poly-Scrim-Kraft; jacketing
   j. PVC: Polyvinyl Chloride
   k. FRP: Fiberglass Reinforced Plastic

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 as required.

1.4 Quality Assurance

A. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products per ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes and cement material containers 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. Maintain ambient conditions required by manufacturers of tapes, adhesives, mastics, cements, and insulation materials.

C. Follow manufacturer's recommended handling practices.

D. Supply fiberglass products that assure excellent IAQ (Indoor Air Quality) performance through Greenguard Certification whenever possible.

E. Fiber Glass and Mold: Fiber glass insulation is not a food source for mold growth. However, mold can grow on almost any material when it becomes wet and contaminated with organic materials. Carefully inspect any insulation that has been exposed to water. If it shows any sign of mold growth it must be discarded. If the material is wet but shows no sign of mold, it should be dried rapidly and thoroughly. If it shows signs of facing degradation from wetting, it should be replaced. 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, 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 equal.

E. Glass Fiber: Knauf 1000° Pipe Insulation meeting ASTM C 547, ASTM C 585, and ASTM C 795; rigid, molded, noncombustible. 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, secured with self-sealing longitudinal laps and butt strips.

F. Glass Fiber: Knauf Pipe & Tank Insulation; 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" (51 mm) thickness per ASTM C 165. Vapor Retarder Jacket: ASJ conforming to ASTM C 1136 Type II.

G. Glass Fiber: Knauf KwikFlex; 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" (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.

H. Fitting Insulation: Pre-formed fiberglass, preformed perlite, mitered fiberglass, mitered perlite or calcium silicate in lieu of PVC systems. These fittings shall be further protected by field-applied fitting covers or metal fittings as necessary.

I. Rigid Fiber Glass Board: Knauf Insulation Board 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.

J. Rigid Fiber Glass Board: Knauf Elevated Temperature (ET) Board meeting ASTM C 612 Type IA, IB, and II; rigid, noncombustible. Maximum Service Temperature: 850°F (232°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.

K. Semi-Rigid Fiber Glass Board: Knauf Elevated Temperature (ET) Panel 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.

L. Flexible Fiber Glass Blanket: Knauf Elevated Temperature (ET) Blanket; 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.

M. Flexible Fiber Glass Blanket: Knauf Friendly Feel® Duct Wrap meeting ASTM C 553 Types I, II and III, and ASTM C 1290; Greenguard compliant; flexible, limited combustible. 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/m^3); exposed areas: Minimum 1.0 PCF (16 kg/m^3).

N. Knauf Duct Liner E-M conforming to ASTM C 1071 Type I and NFPA 90A & 90B; Greenguard compliant, or Knauf Rigid Plenum Liner 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.

O. Fiber Glass Ductwork: Knauf Air Duct Board AGM or Knauf Air Duct Board M. Product shall conform to UL-181 Class 1 and NFPA 90A & 90B and be Greenguard compliant. 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.

P. Phenolic Foam Pre-Insulated Ductwork: Knauf KoolDuct® System. Ductwork System Materials, including the panel, adhesive, tape, sealant, flanges and gasket to be supplied as a matched system by Knauf Insulation, with the entire system listed by UL to the standard UL-181 standard as a Class 1 air duct. k Value: ASTM C 177, 0.13 at 75°F (0.18 at 10°C) mean temperature, for panels manufactured of CFC-free phenolic foam, thermobonded on both sides with a factory applied .001" (25 micron) aluminum foil facing reinforced with a fiberglass scrim. Minimum Density: Panels not less than 3.5 PCF (56 Kg/m^3) with minimum compressive strength of 28 psi (.2 Mpa). Panel Thickness: Standard panel is ⅞" (22 mm) with an R-6.7 (1.2 RSI) or High Performance panel 1$^3/_{32}$" (28 mm) with an R-8.5 (1.5 RSI). Maximum Service Temperature: 176°F (80°C) Maximum Air Velocity: 5000 fpm (25 m/s). Maximum Static Pressure: 4" w.g. (1000 PA) positive (UL rating: 15" w.g. positive; 4.5" w.g. negative).

2.2 Factory Applied Jackets

A. ASJ/SSL: All service jacket with self-sealing lap. White-kraft paper bonded to aluminum foil and reinforced with glass fibers; conforming to ASTM C 1136 Type 1; vapor retarder; with a self-sealing adhesive.

B. ASJ: All service jacket. White-kraft paper bonded to aluminum foil and reinforced with glass fibers.

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.

2.3 Field Applied Jackets

A. 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.

B. Metal: Aluminum, 0.016" (0.406 mm) thick or Stainless Steel, 0.010" (0.254 mm) thick in smooth, corrugated, or embossed finish with factory-applied moisture barrier. Overlap shall be 2" (50 mm) minimum. Fittings shall be die-shaped with factory-applied moisture barrier.

C. 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" (0.406 mm) thick in smooth, corrugated, or embossed finish with factory applied moisture barrier. Overlap shall be 2" (50 mm) minimum. PVC Jacket: Proto Corporation Indoor/Outdoor, UV-resistant, white. Closure shall be solvent weld adhesive or per manufacturer's 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 retarder must be maintained, insulation shall be applied with a continuous, unbroken moisture and vapor seal. 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

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.

C. All ends must be firmly butted and secured with appropriate butt-strip material. On high-temperature piping, double layering with staggered joints may be appropriate. When double layering, the inner layer should not be jacketed.

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 or metal jacketing.

F. For piping exposed to the elements, jacketing shall be Outdoor Weatherable PVC with a minimum thickness of 0.020", or 0.016" thick aluminum or 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. All joints shall be sealed completely along the longitudinal seam and installed so as to shed water. All 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" and be completely weather sealed. PVC Jacketing shall be limited to a maximum 20" OD of the insulation when exposed to direct sunlight. A 6" to 10" unsealed slide joint shall be installed every 25 to 30 lineal feet for the thermal expansion of the pipe and jacketing. Where distance between fittings exceeds 8 lineal feet, an unsealed slide joint of 6" to 10" shall be installed. 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. Cold Piping Insulation

1. On below freezing applications and in high abuse areas, 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 seals at butt joints shall be applied at every fourth pipe section joint and at each fitting to isolate any water incursion.
2. On chilled water systems operating 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

A. Apply on clean, dry surfaces.

B. Cut to appropriate length using manufacturers' stretchout guide to for the specific pipe size. Add an additional 2" (51 mm) to 4" (102 mm) for a staple flap.

C. Wrap around the pipe to ensure proper fit. Staple the lap on 3" (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 piping, appropriate UL approved vapor retarder shall be applied to all longitudinal and circumferential joints before application of butt strip material.

3.5 Equipment Insulation - Fiber Glass

A. Apply insulation with joints firmly butted as close as possible to the equipment surface. Insulation shall be secured as required with adhesive, 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. Vapor retarders shall overlap a minimum of 2" at all seams and be sealed with appropriate pressure-sensitive tape or mastic. All penetrations, facing damage, and mechanical fasteners 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" thick outdoor weatherable PVC, laminated self-adhesive water and weather seal, weatherproof mastic and glass cloth, or metal. All joints shall be positioned so as to shed water; with a minimum 3" overlap, and completely weather sealed. Laminated system shall be installed per manufacturer's recommendations.

D. For high-temperature applications, insulation may be mounted against the hot surface, in H-bar configuration, or in panels mounted away from the operating surface. 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 5% 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 550°F and design thicknesses over 3", insulation shall be applied double-layer with staggered joints. Finish shall be minimum 0.020" 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" thick PVC Jacketing or metal. 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 ⅛" relative to the nominal thickness of the insulation.

C. Adhesive shall conform to ASTM C 916. Adhesive shall be applied to the sheet metal with a 90% minimum coverage. All exposed edges of the duct liner shall be coated with the same adhesive. All rips and tears shall be repaired using an adhesive that conforms to ASTM C 916. All internal duct areas shall be covered with duct liner.

D. Transverse joints shall be firmly butted with no gaps and coated with adhesive. Longitudinal corner joints shall be overlapped and compressed.

E. 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 to obtain specified R-value using a maximum compression of 25%.

B. Installed R-value shall be per ASHRAE 90.1-1999; 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". A 2" tab is provided on Knauf 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" 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" wide using mechanical fasteners on 18" centers. Care should be exercised to avoid over-compression of the insulation during installation. Unfaced Duct Wrap shall be overlapped a minimum of 2" and fastened using 4" to 6" nails or skewers spaced 4" 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

A. Apply on clean, dry surfaces.

B. Cut to appropriate length using manufacturers' stretchout guide to for the specific duct size. Add an additional 2" (51 mm) to 4" (102 mm) for a staple flap.

C. Wrap around the duct to ensure proper fit. Staple the lap on 3" (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" wide glass fabric.

C. All longitudinal and transverse joints having a 1½" staple flap shall be secured with outward-cinching staples on approximate 2" 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" 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 Knauf KoolDuct® System

A. The contractor responsible for the fabrication and installation of phenolic foam pre-insulated ductwork shall be authorized by Knauf Insulation and shall have successfully completed Knauf Insulation's specialized training seminar.

B. All duct construction shall be fabricated, handled and installed in strict accordance with the "Knauf KoolDuct System Design Guide".

C. Duct segments are to be constructed utilizing the V-groove method of fabrication. All external seams shall be taped and all internal seams shall be fully sealed with an unbroken layer of silicon.

D. Each duct segment shall be flanged with either aluminum grip profile or Tiger connectors in accordance with the "Knauf KoolDuct System Design Guide".

E. Duct reinforcement shall be applied to protect against side deformation from both positive and negative pressure per the "Knauf KoolDuct System Design Guide" based on duct size and system pressure.

F. All fabricated duct segment fittings shall be designed in accordance with "SMACNA HVAC Duct Construction Standards" latest edition.

G. Care shall be exercised in the handling and transport of duct segments in order to prevent objectionable aesthetic damage to the outer surface. Storage of duct segments shall be under cover and all material protected from the environment.

H. It is the responsibility of the contractor to ensure that the ductwork system is properly and adequately supported as outlined in the "Knauf KoolDuct System Design Guide"; including 2" (51 mm) channel or uni-strut, and other proprietary supports. It shall be the responsibility of the contractor to ensure the chosen method is compatible with the specific ductwork system. Supports on straight runs of ductwork shall be positioned on centers not to exceed 13' (3.96 m) for duct systems fabricated in 13' (3.96 m) lengths with sides up to 46" (1168 mm). Larger duct sizes and short segments – 4' (1220 mm) long are to be supported on 6' (1.83 m) centers or less in accordance with the "Knauf KoolDuct System Design Guide". Additionally, ductwork shall be supported at changes of direction, at branch and duct connections, tee fittings, and all duct accessories such as dampers, etc. The load of such accessories to the duct system shall be neutralized by the accessory support.

I. Duct air leakage rates shall be in compliance with "SMACNA HVAC Duct Construction Standards" latest edition per applicable leakage class based on pressure.

J. Outdoor Installations: The selection of the appropriate panel as listed in Section 2.3 I (3) shall be determined by the relevant Energy Code. All externally mounted ductwork shall be protected against the elements with a weatherproof finish per the "Knauf KoolDuct System Design Guide". The finish shall be either aluminum clad or coated.

1. Aluminum Clad: Duct segments shall incorporate 0.032" (22 gauge, 0.8 mm) minimum thickness aluminum or alu-zinc sheet which is introduced during the fabrication process as detailed in the "Knauf KoolDuct System Design Guide". All external seams and joints shall be fully sealed with clear silicon. Subsequent to the curing, a 6" (152 mm) strip of self-adhesive, aluminum faced, rubberized bitumen membrane of 60 mil minimum thickness (as supplied by Knauf Insulation) shall be wrapped over all flanged joints, and a 4" (102 mm) strip shall be applied to all other seams on the outer surface of the aluminum duct segment shell if unsealed from the factory. Supports and reinforcement shall be per SMACNA.
2. Coated: The ductwork shall be overcoated with two coats of trowel applied mastic with open weave #10 glass cloth embedded between the two coats as supplied. The coating is to be applied in strict accordance with Knauf Insulation's recommendations over all exposed ductwork including flanged connections. Supports shall be per SMACNA.

K. Aluminum Clad Ductwork for Indoor Installations: Duct segments shall incorporate 0.025" (.6 mm) minimum thickness aluminum sheet which is introduced during the fabrication process as detailed in the "Knauf KoolDuct System Design Guide". Supports shall be per SMACNA.

3.11 Insulation Schedules

A. ASHRAE 90.1-1989 Requirements, Pipe Insulation:

1. The minimum insulation thicknesses 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 Systems Design, install according to NAIMA ETI program (3E Plus) or as specified.

Minimum Pipe Insulation (in.)
(To meet ASHRAE 90.1 Requirements)

Conductivity				Nominal Pipe Diameter (in.)					
Fluid Design Operating Temperature Range, ºF	Conductivity Range Btu-in./(hr•ft²•ºF)	Mean Temperature Rating, ºF		Runouts[a] up to 2	1 and less	1¼ to 2	2½ to 4	5 & 6	8 & up
Heating Systems (Steam, Steam Condensate and Hot Water)									
Above 350	.32-.34	250		1½	2½	2½	3	3½	3½
251-350	.29-.31	200		1½	2	2½	2½	3½	3½
201-250	.27-.30	150		1	1½	1½	2	2	3½
141-200	.25-.29	125		½	1½	1½	1½	1½	1½
105-140	.24-.28	100		½	1	1	1	1½	1½
Domestic and Service Hot Water Systems[b]									
105 and Greater	.24-.28	100		½	1	1	1 ½	1 ½	1 ½
Cooling Systems (Chilled Water, Brine, Refrigerant)[c]									
40-55	.23-.27	75		½	½	¾	1	1	1
Below 40	.23-.27	75		1	1	1½	1½	1½	1½

[a] For minimum thicknesses of insulations not in the conductivity range, use:

$$T = PR[(1 + t/PR)^{K/k} - 1]$$

where

T is minimum insulation thickness for material with conductivity K, in.;
PR is pipe actual outside radius, in.;
t is insulation thickness from above table, in.;
K is conductivity of insulation at the mean temperature indicated in above table for the applicable fluid temperature range, Btu□in./(h□ft²□°F);
k is the lower value of the conductivity range listed in the above table for the applicable fluid temperature range, Btu□in./(h□ft²□°F).

[b] Runouts to individual terminal units not exceeding 12 ft. in length.
[c] Applies to recirculating sections of service or domestic hot water systems and first 8 ft. from storage tank for non-recirculating systems.
[d] These thicknesses are based on energy efficiency considerations only. The required minimum thickness does not consider water vapor transmission and condensation. Additional insulation, vapor retarders, or both, may be required to limit water vapor transmission and condensation.

B.

Necessary Pipe Insulation Thickness to Prevent Surface Condensation
Jacket: ASJ (= 0.9) Wind Speed = 0 mph

Ambient Temperature = 80ºF
Relative Humidity & Operating Temperature

Pipe Size	70% RH					80% RH					90% RH				
	35ºF	40ºF	45ºF	50ºF	55ºF	35ºF	40ºF	45ºF	50ºF	55ºF	35ºF	40ºF	45ºF	50ºF	55ºF
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"	0.5"	1.0"	2.5"	2.5"	2.0"	2.0"	1.5"

Ambient Temperature = 90ºF
Relative Humidity & Operating Temperature

Pipe Size	70% RH					80% RH					90% RH				
	35ºF	40ºF	45ºF	50ºF	55ºF	35ºF	40ºF	45ºF	50ºF	55ºF	35ºF	40ºF	45ºF	50ºF	55ºF
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 Requirements, Duct Insulation

Minimum Duct Insulation R-Value[a]

	Cooling[b]		Heating[c]	
Duct Location	Annual Cooling Degree Days Base 65ºF	Insulation R-Value[d] (h•ft²•ºF/Btu)	Annual Heating Degree Days Base 65ºF	Insulation R-Value[d] (h•ft²•ºF/Btu)
Exterior of building	Below 500 500 to 1150 1151 to 2000 Above 2000	3.3 5.0 6.5 8.0	Below 1500 1500 to 4500 4501 to 7500 Above 7500	3.3 5.0 6.5 8.0
Inside of building envelope or in unconditioned spaces[g]				
TD[e] ≤ 15	—	None Required		None Required
40 ≥ TD[e] > 15	—	3.3	—	3.3
nTD[e] > 40	—	5.0[f]	—	5.0[f]

[a] Insulation R-values shown are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and condensation. Additional insulation, vapor retarders or both, may be required to limit vapor transmission and condensation. For ducts that are designed to convey both heated and cooled air, duct insulation shall be as required by the most restrictive condition. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of the above table or the most restrictive building envelope criterion.

[b] Cooling ducts are those designed to convey mechanically cooled air or return ducts in such systems.

[c] Heating ducts are those designed to convey mechanically heated air or return ducts in such systems.

[d] Insulation resistance measured on a horizontal plane in accordance with ASTM C518-85 at a mean temperature of 75°F at the installed thickness.

[e] TD is defined as the temperature difference at design conditions between the space within which the duct is located and the design air temperature in the duct.

[f] Insulation resistance for runouts to terminal devices less than 10' in length need not exceed 3.3 (h•ft²•°F) / Btu.

[g] Unconditioned spaces include crawl spaces and attics.

D. UCC Code Requirements

Compliance With Uniform Construction Code

Table 503.3.3.3 Minimum Duct Insulation

Annual Heating Degree Days	Insulation R-value (h•ft²•°F)/Btu			
	Ducts in unconditioned attics or Outside building		Ducts in unconditioned basements, crawl spaces, garages, and other unconditioned spaces	
	Supply	Return	Supply	Return
Below 1,500	8	4	4	0
1,500 to 3,500	8	4	6	2
3,501 to 7,500	8	4	8	2
Above 7,500	11	6	11	2

1. All ductwork must be sealed along longitudinal and transverse joints.
2. National Climatic Data Center lists the Annual Heating Degree Days for most locations throughout the USA.
   R - value installed shall correspond to the requirements stated based upon the Annual Heating Degree Days.

Systems to Achieve Required R-Values For ASHRAE 90.1 and UCC

R–2:

1. Air Duct Board–1" thick (R 4.3)
2. Sheetmetal ductwork with .75 PCF 1½" Duct Wrap (R 4.2 @ 25% compression)
3. Sheetmetal ductwork with 1.5 PCF 1" Duct Liner (R 3.6–R 4.2)

R–4:

1. Air Duct Board–1" thick (R 4.3)
2. Sheetmetal ductwork with .75 PCF 1½" Duct Wrap (R 4.2 @ 25% compression)
3. Sheetmetal ductwork with 1.5 PCF 1" thick rotory* Duct Liner (R 4.2)

R–5:

1. Air Duct Board–1½" thick (R 6.5)
2. Sheetmetal ductwork with .75 PCF 2" Duct Wrap (R 5.6 @ 25% compression)
3. Sheetmetal ductwork with 1.5 PCF 1½" thick rotory* Duct Liner (R 6.0)

R–8:

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

* Textile Duct Liner will not achieve the required R-Value.

E.

Minimum Duct Wrap R-Value (Installed) To Prevent Surface Condensation
Jacket: Aged Aluminum Foil or Galvanized Sheet Metal (Å = 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	**	**	**	**

E.

Fiberglass Ductwork-Reinforcement Schedules
1. Tie Rod System (Positive Pressure Only)

		Type EI-475 Board			Type EI-800 Board		
Positive Static Pressure	Inside Duct Dimension (inches)	No. Rods Across Dimension	Maximum Longitudinal Spacing	No. Rods per 4' Section	No. Rods Across Dimension	Maximum Longitudinal Spacing	No. Rods per 4' 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.	0-15	*	*	*	*	*	*
	16-18	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" 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.

E.

Fiberglass Ductwork-Reinforcement Schedules
2. Channel System (Positive and Negative Pressure)

Static Pressure		Max. Inside Duct Dimension (inches)	Type EI-475 Board			Type EI-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.

F.

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" and 48" and greater than 24" high	6 ft.
Less than 48" wide and height between 12" and 24"	8 ft.
Width 24" or less and height greater than 12"	8 ft.

END OF HVAC IINSULATION—SECTION 230700

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NOTES

Knauf Insulation GmbH complies with ISO 9002 in the prevention, detection and correction of problems in production and service areas.

Knauf Duct Wrap products are certified for indoor air quality as a low emitting product by The GREENGUARD Environmental Institute™ to both the GREENGUARD Certification Program℠ and the more stringent GREENGUARD For Children and Schools™ standard. www.greenguard.org.

Knauf Duct Liner E•M and Rigid Plenum Liner products are certified for indoor air quality by The GREENGUARD Environmental Institute™, a global, non-profit organization, providing the world's leading guide to certified low emitting interior products and building materials through independent, indoor air quality laboratory testing. www.greenguard.org.

At Knauf Insulation, we manufacture a wide variety of products that serve a common goal, helping to make the most of our planet's energy resources. A family-owned global company, we understand and are committed to high standards in quality, performance and environmental responsibility. Every step we take today toward energy conservation helps ensure better lives for generations to come.

LEED Eligible Product

Use of this product may help building projects meet green building standards as set by the Leadership in Energy and Environmental Design (LEED) Green Building Rating System.
Credit 4.1 - 4.2 Recycled Content
Credit 5.1 - 5.2 Regional Materials