polyguard MECHANICAL

# Polyguard PolyPhen™ Insulation

## Guide Specification – Piping Systems

**1.0 General**

1.1 Scope:

This document pertains to installation guidelines for Polyguard® PolyPhen™, vapor barriers and jacketing for piping applications, elbows, fittings and valves for the following applications. \

- 1.1.1 Chilled Piping Service (35°F to70°F)
- 1.1.2 Hot Piping Service (90°F to 250°F)

1.2 Applicable ASTM Standards:

- 1.2.1 C209 Standard test method for water absorption of cellular plastics
- 1.2.2 C450 Standard practice for fabrication of thermal insulation fitting covers for nps and vessel lags
- 1.2.3 C518 Standard test method for steady – state thermal transmission properties by means of heat flow meter apparatus
- 1.2.4 C585 Standard practice for inner and outer diameters of thermal insulation for nominal pipe and tubing
- 1.2.5 C1126 Standard specification for faced or unfaced rigid Cellular Phenolic thermal insulation
- 1.2.6 C1136 Standard specification for flexible, low permeance vapor retarders for thermal insulation
- 1.2.7 D696 Standard test method for coefficient of linear thermal expansion of plastics between
- 1.2.8 -30°C and +30°C with a vitreous silica dilatometer
- 1.2.9 D1621 Standard test method for compressive properties of thermal rigid cellular plastics
- 1.2.10 D1623 Standard test method for density of thermal rigid cellular plastics
- 1.2.11 ASTM D-2126, 2127, 2128 Standard test method for thermal and humid aging
- 1.2.12 E84 Standard test method for flame spread / smoke developed using tunnel burn test.
- 1.2.13 E96 Standard test method for water transmission of cellular plastics

1.3 Related Documents:

- 1.3.1 Specification 15088 – Pipe Painting
- 1.3.2 Polyguard PolyPhen Data Sheet
- 1.3.3 Polyguard PolyPhen MSDS

1.4 Definitions:

- 1.4.1 Rigid PolyPhen™ Phenolic Insulation meets ASTM C1126 Type III Standard Specification for Rigid Cellular Phenolic Thermal Insulation and the standards and tests listed above.
- 1.4.2 Chilled Service Piping: Refers to below ambient piping in the 35°F to 70°F range
- 1.4.3 Hot Water Piping: Refers to piping in the 90°F to 250°F range
- 1.4.4 Nominal Insulation Thickness: Refers to the normal thickness that insulation fabricators will provide based on standard tables, pipe sizes and wall thicknesses
- 1.4.5 OD: Refers to the outer diameter of the insulation and/or finish covering
- 1.4.6 R-Value: 1 $h \cdot ft^2 \cdot °F/BTU$ Is the unit used for thermal resistance
- 1.4.7 K-Factor: $BTU/ft^2/°F/hr$ is the reciprocal or R-Value at a 1 inch thickness.
- 1.4.8 SSL: Acronym for self-sealing lap. Often found on vapor barrier films and membranes.

1.5 Quality Assurance:

- 1.5.1 Polyguard® PolyPhen™ Insulation shall not be produced with, or contain, any of the United States EPA regulated CFC Compounds listed in the Montreal Protocol of the United Nations Environmental Program.
- 1.5.2 Installation guidelines and thickness recommendations must be followed by the skilled installer in a manner of good workmanship.

1.6 Delivery, Handling & Storage:

- 1.6.1 Protect insulation from physical damage and excessive moisture.
- 1.6.2 Store indoors and keep free from exposure to UV, rain, hail, snow and wind.

1.6.3 Handle insulation sections carefully so corners are not broken off creating voids. Inspect for lags or gaps in longitudinal and butt joints. Vapor barrier must be intact and free of holes or voids.

**2.0 Products**

2.1 Insulation:

2.1.1 Insulation Type is PolyPhen – Phenolic Bun: ASTM C1126 with flame spread and smoke developed indexes of 25 / 50, respectively, up to 4" insulation thickness per ASTM E84.

a. Rigid Close Cell Foam Insulation
b. Comply with ASTM C1126, Type III, density 2.5 lb/cu ft, minimum compressive strength 25 psi at 10 percent deformation (ASTM D1621)
c. Thermal resistance: K-Factor of .18 @ 75°F Mean
d. Water absorption: Maximum 2.5 % by volume per ASTM C209
e. Surface Burning Characteristics: (ASTM E84) up to 4"
   i) Flame Spread: 25
   ii) Smoke Developed: 50

2.1.2 Pipe sections, fittings, valves and vessels to be fabricated from bun stock by an authorized fabricator and must adhere to the appropriate standard listed in sections 1.1 and 1.2.

2.1.3 At 90 and 45 degree elbows, valves and fittings, pre-molded 2 piece system shall be installed that fits snug on the pipe or component. Mitered elbows and fiberglass filled PVC elbows in particular are not recommended for chilled service piping and colder.

2.1.4 Vessels, heads, segments & bodies shall be fabricated to fit the curves and contours of the vessel being insulated.

2.1.4.1 Vessel head segments to be curved and cut to minimize or eliminate voids at the head section. Two part spray applied polyurethane foam shall be used to fill in voids.

2.1.4.2 Vessel segments shall be fabricated per ASTM C450

2.2 Joint Sealant , Adhesive & Mastic, Vapor Retarder Tape

2.2.1 Joint Sealant for all joints of insulation shall be vapor barrier type, non-hardening, flexible with service temp range of -50°F to 200°F.

2.2.1.1 Childers, CP-70

2.2.1.2 Boss 368

2.2.2 Adhesive used to apply vapor retarder to insulation shall be one of the following:

2.2.2.1 Childers, 85-50

2.2.2.2 Childers, 85-60

2.2.3 Mastic

2.2.3.1 Childers, CP-35

2.2.4 Vapor Guard Tape:

2.2.4.1 Polyguard 1677 Tape

2.3 Vapor Barrier:

2.3.1 Vapor Barrier should have a maximum permeance of 0.015 after final application. Where vapor barrier tape is required to seal butt and longitudinal joints or for wrapping of fittings, use a compatible tape from the same manufacturer as the vapor barrier.

2.3.2 For Chilled and Cold service on outdoor piping, rubberized asphalt based vapor barriers are recommended since they are more puncture resistant and are self-healing. Also, for extreme Cryogenic piping, where triple layers of insulation are required, a rubberized asphalt vapor barrier is recommended for the primary and a film type vapor barrier is recommended as a secondary vapor barrier.

2.3.3 Vapor Barriers are applied to the outside surface of the insulation on pipe covering, valves, fittings and vessels. They are intended to minimize water and moisture migration from the external environment and keep it away from the insulation and piping. Moisture causes a reduction in thermal performance of the insulation and can cause pipe corrosion if trapped between the pipe and insulation.

2.3.4 Acceptable Vapor Barriers
2.3.4.1 Polyguard Zero Perm and Zero Perm A
2.3.4.2 Polyguard Insulrap 30

2.4 Protective Jacketing:

2.4.1 Cladding: Cladding should have a maximum permeance of 0.000 or better after final application.

2.4.2 Rubberized asphalt based cladding products are recommended for exterior use. These products have the perm rating of a vapor barrier, yet are UV stable in exterior environments. Products are available in silver or white, smooth or embossed. All products must have a 10 year warranty.

2.4.3 Acceptable Cladding Products: Exterior
2.4.3.1 Polyguard Alumaguard
2.4.3.2 Polyguard Alumaguard All Weather
2.4.3.3 Polyguard Alumaguard Cool Duct

2.4.4 Acceptable Cladding Products: Interior
2.4.4.1 Alumaguard Lite (White or Silver)

2.4.5 PVC Jacketing for Indoor Applications:
2.4.5.1 PVC jacket is not a vapor barrier; it provides some mechanical protection to the insulation and vapor barrier, aesthetics and color coding.
2.4.5.2 30 mil thick PVC is recommended on pipe sections and fittings in standard applications. A 40 mil thickness is recommended in spray or wash down areas.
2.4.5.3 Joints shall be solvent welded with manufacturer recommended product.
2.4.5.4 PVC jacketing for fittings, tees, elbows, valves etc. should be heavy duty fitting covers.
2.4.5.5 Pipe sections to be covered with PVC sectional pieces.
2.4.5.6 Refer to the PVC Manufacturer for temperature limitations.

2.4.6 Acceptable PVC Manufacturers:
2.4.6.1 PIC Plastics
2.4.6.2 Proto
2.4.6.3 Ceel Co

2.4.7 Metal Jacketing for Outdoor Applications:
2.4.7.1 Metal jacketing is not a vapor barrier, it is designed to protect the insulation and vapor barrier from physical abuse from weather, mechanical wear or other damage. The jacketing shall be Aluminum Alloy 1100 meeting ASTM B209, and must have a polysurlyn moisture barrier on the back side.
2.4.7.2 Material recommendations:
2.4.7.2.1 0.016 inch thick for pipe sections
2.4.7.2.2 0.020, 0.024 or 0.032 should be considered in high abuse areas
2.4.7.2.3 Stucco finish is recommended
2.4.7.2.4 Banding should be stainless steel T304/T316 ½” x 0.020” with stainless steel wing seal.
2.4.7.3 Recommended Manufacturers:
2.4.7.3.1 RPR Products
2.4.7.3.2 Standard Metal
2.4.7.3.3 Ideal Metal
2.4.7.3.4 ITW Insulation

2.6 Pipe & Hanger Support Saddles:

2.6.1 Pipe support, load bearing insulation shall be fabricated in 180 degree sections from 2.5 LB Polyguard® PolyPhen™ for up to 6" pipe diameter. Saddle length must be adjusted to minimize loading and prevent excessive compression of the insulation. Polyguard® PolyPhen™ heavy densities of 3.75, 5 and 7.5 are available for larger pipe diameter pipe supports

2.6.2 Load bearing shields shall be provided by the contractor.

2.6.3 Sliding saddles are recommended for use on any type of jacket system. They absorb all of the abuse from expansion and contraction of the piping system. The jacket will remain in serviceable condition much longer using a sliding saddle. Sliding saddles have enough give for expansion and contraction that they don't end up on the floor or falling from the roof. They are less expensive than roller hangers.

2.6.4 Recommended Saddles:

2.6.4.1 Polyguard AlumaGlide.

2.7 Pipe Protection:

2.7.1 All piping on cold systems should have a coating to protect against corrosion. With a good vapor barrier and tightly closed cell insulation, the chances of moisture intrusion are reduced significantly. Even with this reduced risk, pipe protection is still recommended. These systems will be in service for a long time, and there will be numerous opportunities for physical damage to the system. If moisture gets trapped between the pipe and insulation, corrosion will occur.

2.7.2 Reactive Gel is recommended for pipe corrosion protection.

2.7.2.1 Reactive Gel provides a moisture and oxygen barrier that expands, contracts and moves with the entire piping system.

2.7.2.2 Reactive Gel "converts" the surface of ferrous metals to enhance corrosion resistance and buffers the pH of any moisture that penetrates into the system to minimize corrosion.

2.7.2.3 Apply in 25 mil thickness as recommended by the manufacturer

2.7.3 Recommended Products

2.7.3.1 Polyguard RG-2400LT (Piping and vessels -100°F to 250°F)

2.7.3.2 Polyguard RG-CHW (Piping 33°F to 160°F)

2.7.3.3 Polyguard RG-2400ET (Hot lines up to 350°F)

2.8 Miscellaneous Materials:

2.8.1 Fiber reinforced (strapping) filament tape shall be a minimum ¾ inches wide and shall be used to secure insulation pipe and fitting sections to the piping system. A minimum of 3 pieces shall be wrapped circumferentially around the insulation for each section of insulation. Tape shall be overlapped 50 percent onto itself.

2.8.2 Spray urethane foam, single component available in aerosol cans shall be used to fill minor gaps between sections of insulation.

2.8.3 Flexible closed cell elastomeric insulation supplied as sheet or preformed pipe covering may be used to form expansion / contraction joints. Note: Use of a non-halogenated elastomeric insulation is recommended when reactive gel is not used to protect the piping system from corrosion.

**3.0 Execution**

3.1 Preparation

3.1.1 Insulation should not be stored or installed around welding, abrasion, or anything that would likely cause damage to the material. Install insulation after these jobs are complete.

3.1.2 Surface Preparation

3.1.2.1 Before insulation or reactive gel (if applicable) is installed, all pipe surfaces should be free of moisture, dirt, oil, grease, loose scale, rust or other abnormal material.

3.1.2.2 If loose scale or surface corrosion are present, clean using a wire brush (SP-2).

3.2 Pipe Protection (If required by end user)

3.2.1 After preparation steps above are complete, install reactive gel on the pipe.

3.2.2 Brush or glove apply reactive gel to the piping to approximately 30mil wet film thickness (wft).

3.2.3 Use an AccuTrowel to screed the gel to a 25mil finish thickness.

3.2.4 Apply insulation immediately after reactive gel application is complete. Insulation can be applied within minutes of gel application. For best results apply insulation right behind gel application.

3.3 Insulation Installation (including vapor barrier)

3.3.1 Inspect insulation to make sure it is tightly butted and free of gaps and voids.

3.3.2 Inspect vapor barrier and other jacketing to make sure it is intact and free of damage.

3.3.3 Apply insulation to the piping with longitudinal joints at 3 and 9 o'clock positions and butt joints staggered. For chilled service, adhesives or joint sealant, and staggered butt joints may not be required. Refer to the end user's specification for specific requirements.

3.3.4 Use joint sealant listed above in section 2.2 for longitudinal and butt joints

3.3.5 Secure each layer of insulation with tape or bands and tighten bands without deforming insulation materials. Orient longitudinal joints between half sections in 3 and 9 o'clock positions on the pipe.

3.3.6 Vapor barrier to be applied on site, or factory applied is also acceptable.

3.3.7 Insulation for chilled service piping can have factory applied vapor barrier or the vapor barrier can be installed on site.

3.3.7.1 For Insulation with factory applied jackets with vapor barriers, do not staple longitudinal tabs. Instead secure tabs using additional adhesive or tape to strengthen SSL bond if needed.

3.3.8 All insulation shall be tightly butted and free of voids and gaps at all joints.

3.3.9 Vapor Stop Application

3.3.9.1 Apply vapor stops every 20-30 feet of straight runs, before and after every exposed valve or fitting and at terminations both around the pipe and over the butt joint of the insulation. Vapor stops must be continuous and tie in to the vapor barrier to minimize moisture penetration. Please see diagram 3 for further detail.

3.3.9.2 Apply either Vapor Guard tape or mastic – fab – mastic application.

3.3.10 Field Applied Vapor Barriers:

3.3.10.1.1 Field applied vapor barriers should be applied without staples or nails. Apply vapor barrier so that longitudinal joint is facing down ward (to shed water) at 4 o'clock position.

3.3.10.1.2 Apply film type vapor barrier with one of the recommended adhesives listed in section 2.2 or with compatible vapor barrier tape. Longitudinal overlap should be 2" for adequate adhesion. Apply SSL to firmly close longitudinal joints. Rubberized asphalt vapor barriers have a peel and stick overlap that is sufficient to seal membrane in installation temperatures above 50°F. For below 50°F installation temperatures, an activator is necessary.

3.3.10.1.3 Apply tape strips at butt joints to secure insulation sections and further hold vapor barrier in place.

3.3.10.1.4 Vapor barrier must be continuous on pipe sections and should be installed in a cigarette fashion.

3.3.11 Insulation Installation on Pipe Flanges:

3.3.11.1 Install preformed pipe insulation to outer diameter of pipe flange.

3.3.11.2 Make width of insulation section same as overall width of flange and bolts, and make thickness same as adjacent pipe insulation, not to exceed 1.5".

3.3.11.3 Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of styrene block insulation of same thickness as pipe insulation.

3.3.12 Insulation Installation on Pipe Fittings and Elbows:

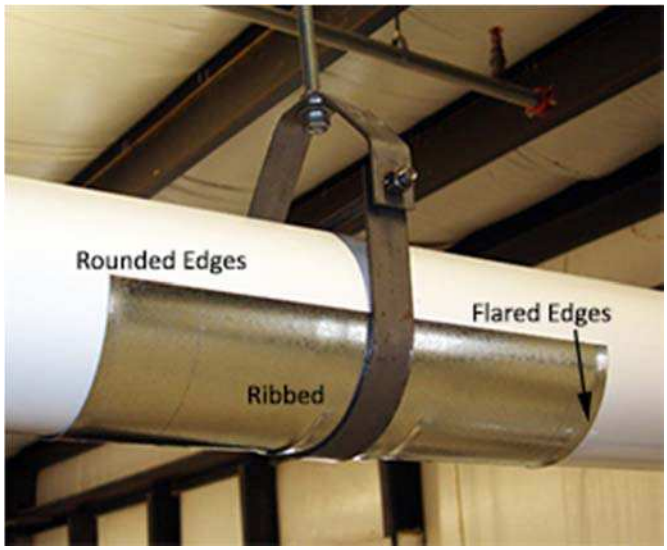
Install preformed insulation sections of same material as straight segments of pipe insulation. Joints should be consistent with pipe sections if sealant is required.
Spiral wrap vapor retarder tape with ½" overlap to secure elbow or fitting tightness and seal up joint.

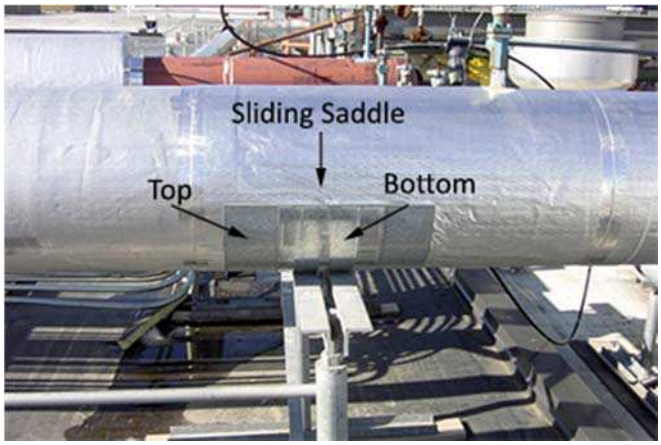
3.3.13 Insulation Installation on Valve and Pipe Specialties

Install preformed section of polystyrene insulation to valve body.
Arrange insulation to permit access to packing and allow valve operation without disturbing insulation.
Install insulation to flanges as specified for flange insulation application.

**Hangers:** Poor hanger system design is often a cause of problems on cold systems. Hanger supports and insulation that supports the piping need to be specified and installed correctly. It is very common for moisture to enter the system at the hangers. Hangers can tear the jacket and vapor barrier if not applied correctly. Sliding saddles are a very good idea on ammonia systems. Piping systems expand and contract a lot and in most cases the abuse is taken by the jacket. In a sliding saddle the abuse is taken by the top side of the saddle which is designed to take the abuse.

If a traditional style saddle is used, rounded edges and flared out ends are a good idea so that they can't puncture the jacket or vapor barrier. The supporting insulation can be a variety of Polyphen densities ranging from 2.5LB up to 7.5LB densities. Please see our table in Exhibit A.




**Sliding Saddle Advantages:**

- Designed to take pipe expansion and contraction
- Sliding system takes the abuse
- Top part of saddle is adheres to pipe jacket
- Sharp edges are rounded and flared to reduce risk of jacket puncture
- Teflon coated to ensure good slide mechanism
- Wide variety of sizes available

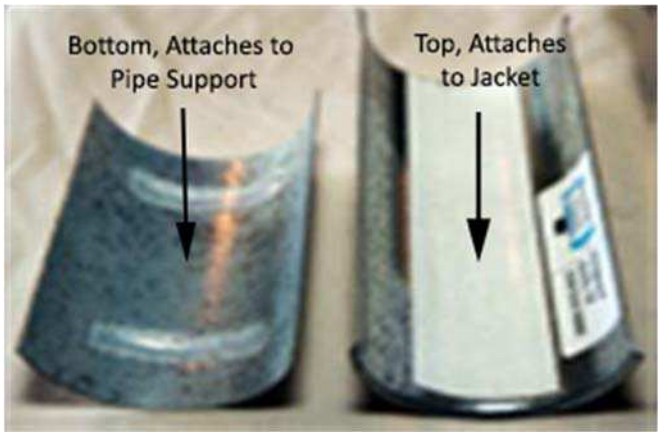


Exhibit A:

Polyphen, Hanger Support Table

Schedule 40 Pipe with H2O, 5X Safety Factor, Insulation weight calculated with 2” Polyphen 2.5LB pipe insulation

| Pipe Size | Shield Length | Guage | Industry Suggest Max Span, Ln.Ft. | Max Span Ln.Ft. with Polyphen Insert | Pipe Weight Lbs. | H2O Weight Lbs. | Insulation Weight Lbs. | Total Weight Lbs. |
|---|---|---|---|---|---|---|---|---|
| Polyphen 2.5LB Pipe Sizes 1”-4” | | | | | | | | |
| 1 | 12” | 18 | 7 | 29* | 1.68 | .38 | 1.3 | 3.35 |
| 1.5 | 12” | 18 | 9 | 24* | 2.72 | .88 | 1.96 | 5.56 |
| 2 | 12” | 18 | 10 | 22* | 3.66 | 1.45 | 2.6 | 8.91 |
| 2.5 | 12” | 18 | 11 | 18* | 5.8 | 2.07 | 3.28 | 12.82 |
| 3 | 12” | 18 | 12 | 16* | 7.58 | 3.2 | 3.92 | 16.67 |
| 3.5 | 12” | 18 | 13 | 15* | 9.12 | 4.3 | 4.46 | 20.11 |
| 4 | 12” | 18 | 14 | 14 | 10.8 | 5.5 | 5.22 | 24.13 |
| Polyphen 3.75LB recommended for pipe sizes 5”-6” | | | | | | | | |
| 5 | 12” | 18 | 16 | 17* | 14.63 | 8.66 | 6.54 | 33 |
| 6 | 12” | 18 | 17 | 17 | 19 | 12.51 | 7.85 | 43.30 |
| Polyphen 5LB recommended for pipe sizes 8”-14” | | | | | | | | |
| 8 | 18” | 16 | 19 | 35* | 28.6 | 21.68 | 10.46 | 60.75 |
| 10 | 18” | 16 | 22 | 30* | 40.52 | 34.10 | 13.08 | 87.70 |
| 12 | 18” | 16 | 23 | 28* | 49.6 | 49 | 15.7 | 114.30 |
| 14 | 18” | 16 | 25 | 26* | 54.6 | 59.7 | 18.32 | 132.62 |
| Polyphen 7.5LB recommended for pipe sizes 16”-30” | | | | | | | | |
| 16 | 18” | 16 | 27 | 38* | 62.6 | 79.1 | 20.93 | 162.63 |
| 18 | 18” | 16 | 28 | 36* | 70.6 | 101.2 | 23.56 | 195.36 |
| 20 | 18” | 16 | 30 | 34* | 78.6 | 126 | 26.2 | 230.80 |
| 24 | 24” | 16 | 32 | 40* | 94.6 | 183.8 | 31.4 | 310 |
| 30 | 24” | 16 | 32 | 35* | 118.7 | 291 | 39.26 | 450 |

* Max Span should not exceed industry suggested max span.

Schedule 40 Pipe with H2O, 3X Safety Factor, Insulation weight calculated with 2” Polyphen 2.5LB pipe insulation

| Pipe Size | Shield Length | Guage | Industry Suggest Max Span, Ln.Ft. | Max Span Ln.Ft. with Polyphen Insert | Pipe Weight Lbs. | H2O Weight Lbs. | Insulation Weight Lbs. | Total Weight Lbs. |
|---|---|---|---|---|---|---|---|---|
| Polyphen 2.5LB Pipe Sizes 1”-4” | | | | | | | | |
| 1 | 12” | 18 | 7 | 38* | 1.68 | .38 | 1.3 | 3.35 |
| 1.5 | 12” | 18 | 9 | 34* | 2.72 | .88 | 1.96 | 5.56 |
| 2 | 12” | 18 | 10 | 26* | 3.66 | 1.45 | 2.6 | 8.91 |
| 2.5 | 12” | 18 | 11 | 22* | 5.8 | 2.07 | 3.28 | 12.82 |
| 3 | 12” | 18 | 12 | 20* | 7.58 | 3.2 | 3.92 | 16.67 |
| 3.5 | 12” | 18 | 13 | 19* | 9.12 | 4.3 | 4.46 | 20.11 |
| 4 | 12” | 18 | 14 | 18* | 10.8 | 5.5 | 5.22 | 24.13 |
| 5 | 12” | 18 | 16 | 16 | 14.63 | 8.66 | 6.54 | 33 |
| Polyphen 3.75LB recommended for pipe sizes 6”-14” | | | | | | | | |
| 6 | 12” | 18 | 17 | 24* | 19 | 12.51 | 7.85 | 43.30 |
| 8 | 18” | 16 | 19 | 33* | 28.6 | 21.68 | 10.46 | 60.75 |
| 10 | 18” | 16 | 22 | 29* | 40.52 | 34.10 | 13.08 | 87.70 |
| 12 | 18” | 16 | 23 | 26* | 49.6 | 49 | 15.7 | 114.30 |
| 14 | 18” | 16 | 25 | 25 | 54.6 | 59.7 | 18.32 | 132.62 |
| Polyphen 5LB recommended for pipe sizes 16”-30” | | | | | | | | |
| 16 | 18” | 16 | 27 | 40* | 62.6 | 79.1 | 20.93 | 162.63 |
| 18 | 18” | 16 | 28 | 38* | 70.6 | 101.2 | 23.56 | 195.36 |
| 20 | 18” | 16 | 30 | 32* | 78.6 | 126 | 26.2 | 230.80 |
| 24 | 24” | 16 | 32 | 42* | 94.6 | 183.8 | 31.4 | 310 |
| 30 | 24” | 16 | 32 | 37* | 118.7 | 291 | 39.26 | 450 |

* Max Span should not exceed industry suggested max span.

**Exhibit B:**

**Thickness Tables:** All Tables Calculated using 3EPlus v4.1. Table lists the greater thickness required to prevent condensation or limit heat gain to a maximum 8 BTU/ hr/ sq ft

**INDOOR MILD CONDITIONS**
**Service Temperature, °F**

| Diameter | 0 | 10 | 20 | 30 | 40 | 50 | 100 | 150 | 200 | 250 |
|---|---|---|---|---|---|---|---|---|---|---|
| ½ | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2 |
| ¾ | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2 |
| 1 ½ | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2.5 |
| 2 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2.5 |
| 2.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2.5 | 2.5 |
| 3 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2.5 | 2.5 |
| 4 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2.5 | 3 |
| 5 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1.5 | 3 | 3 |
| 6 | 1.5 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1.5 | 3 | 3 |
| 8 | 1.5 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1.5 | 3 | 3.5 |
| 10 | 1.5 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1.5 | 3 | 3.5 |
| 12 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1.5 | 3 | 3.5 |
| 14 | 2 | 1.5 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1.5 | 3.5 | 3.5 |
| 16 | 2 | 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 2 | 3.5 | 4 |
| 18 | 2 | 2 | 2 | 1.5 | 1.5 | 1 | 1 | 2 | 3.5 | 4 |
| 20 | 2 | 2 | 2 | 2 | 1.5 | 1 | 1 | 2 | 3.5 | 4 |
| 24 | 2 | 2 | 2 | 2 | 1.5 | 1 | 1 | 2 | 3.5 | 4.5 |
| 30 | 2 | 2 | 2 | 2 | 1.5 | 1 | 1 | 2 | 3.5 | 4.5 |

Design Criteria: Ambient Temp: 70°F, Relative Humidity 50%. Dew Point 50.5°F Wind Speed: 0 MPH, Jacket: (Zero Perm) 0.9 Emissivity

**INDOOR MODERATE CONDITIONS**
**Service Temperature, °F**

| Diameter | 0 | 10 | 20 | 30 | 40 | 50 | 100 | 150 | 200 | 250 |
|---|---|---|---|---|---|---|---|---|---|---|
| ½ | 1.5 | 1 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2 |
| ¾ | 1.5 | 1 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2 |
| 1 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2 |
| 1 ½ | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2 |
| 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2.5 |
| 2.5 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1.5 | 2.5 | 2.5 |
| 3 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1.5 | 2.5 | 2.5 |
| 4 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1.5 | 2.5 | 3 |
| 5 | 2 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1.5 | 3 | 3 |
| 6 | 2 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1.5 | 3 | 3 |
| 8 | 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1.5 | 3 | 3.5 |
| 10 | 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1.5 | 3 | 3.5 |
| 12 | 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1.5 | 3 | 3.5 |
| 14 | 2 | 2 | 1.5 | 1.5 | 1 | 1 | 1 | 2 | 3.5 | 3.5 |
| 16 | 2 | 2 | 1.5 | 1.5 | 1 | 1 | 1 | 2 | 3.5 | 4 |
| 18 | 2 | 2 | 2 | 1.5 | 1.5 | 1 | 1 | 2 | 3.5 | 4 |
| 20 | 2 | 2 | 2 | 1.5 | 1.5 | 1 | 1 | 2 | 3.5 | 4 |
| 24 | 2 | 2 | 2 | 2 | 1.5 | 1 | 1 | 2 | 3.5 | 4.5 |
| 30 | 2 | 2 | 2 | 2 | 1.5 | 1 | 1 | 2 | 3.5 | 4.5 |

Design Criteria: Ambient Temp: 85°F, Relative Humidity 80%. Dew Point 78.1°F Wind Speed: 0 MPH, Jacket: (Zero Perm) 0.9 Emissivity

**OUTDOOR Moderate CONDITIONS**
**Service Temperature, °F**

| Diameter | 0 | 10 | 20 | 30 | 40 | 50 | 100 | 150 | 200 | 250 |
|---|---|---|---|---|---|---|---|---|---|---|
| ½ | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2.5 |
| ¾ | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2.5 |
| 1 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2.5 |
| 1 ½ | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1.5 | 2 | 2.5 |
| 2 | 2 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1.5 | 2 | 3 |
| 2.5 | 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1.5 | 2 | 3 |
| 3 | 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1.5 | 2.5 | 3 |
| 4 | 2 | 2 | 1.5 | 1.5 | 1 | 1 | 1 | 1.5 | 2.5 | 3.5 |
| 5 | 2 | 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1.5 | 3 | 3.5 |
| 6 | 2 | 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1.5 | 3 | 3.5 |
| 8 | 2 | 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1.5 | 3 | 3.5 |
| 10 | 2 | 2 | 1.5 | 1.5 | 1.5 | 1 | 1 | 1.5 | 3 | 4 |
| 12 | 2 | 2 | 2 | 1.5 | 1.5 | 1 | 1 | 1.5 | 3 | 4 |
| 14 | 2 | 2 | 2 | 1.5 | 1.5 | 1 | 1 | 1.5 | 3 | 4 |
| 16 | 2 | 2 | 2 | 1.5 | 1.5 | 1 | 1 | 1.5 | 3 | 4 |
| 18 | 2 | 2 | 2 | 1.5 | 1.5 | 1 | 1 | 1.5 | 3 | 4 |
| 20 | 2 | 2 | 2 | 1.5 | 1.5 | 1 | 1 | 2.0 | 3 | 4.5 |
| 24 | 2.5 | 2 | 2 | 2 | 1.5 | 1 | 1 | 2 | 3 | 4.5 |
| 30 | 2.5 | 2 | 2 | 2 | 1.5 | 1 | 1 | 2 | 3 | 4.5 |

**Design Criteria: Ambient Temp: 90°F, Relative Humidity 70%. Dew Point 78.9°F Wind Speed: 3 MPH, Jacket: (Painted Aluminum) 0.5 Emissivity**

**OUTDOOR Severe CONDITIONS**
**Service Temperature, °F**

| Diameter | 0 | 10 | 20 | 30 | 40 | 50 | 100 | 150 | 200 | 250 |
|---|---|---|---|---|---|---|---|---|---|---|
| ½ | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2.5 |
| ¾ | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2.5 |
| 1 | 1.5 | 1.5 | 1.5 | 1.5 | 1 | 1.5 | 1 | 1 | 1.5 | 2.5 |
| 1 ½ | 2 | 1.5 | 1.5 | 1.5 | 1 | 1.5 | 1 | 1 | 2 | 2.5 |
| 2 | 2 | 2 | 1.5 | 1.5 | 1 | 1.5 | 1 | 1 | 2 | 3 |
| 2.5 | 2 | 2 | 1.5 | 1.5 | 1 | 1.5 | 1 | 1 | 2 | 3 |
| 3 | 2.5 | 2 | 2 | 2 | 1.5 | 1.5 | 1 | 1.5 | 2 | 3 |
| 4 | 2.5 | 2.5 | 2 | 2 | 1.5 | 1.5 | 1 | 1.5 | 2.5 | 3.5 |
| 5 | 3 | 2.5 | 2 | 2 | 1.5 | 1.5 | 1 | 1.5 | 2.5 | 3.5 |
| 6 | 3 | 3 | 2.5 | 2 | 1.5 | 1.5 | 1 | 1.5 | 2.5 | 3.5 |
| 8 | 3 | 3 | 2.5 | 2.5 | 2 | 1.5 | 1 | 1.5 | 2.5 | 3.5 |
| 10 | 3.5 | 3 | 3 | 2.5 | 2 | 1.5 | 1 | 1.5 | 2.5 | 4 |
| 12 | 3.5 | 3.5 | 3 | 2.5 | 2 | 1.5 | 1 | 1.5 | 3 | 4 |
| 14 | 4 | 3.5 | 3 | 3 | 2 | 2 | 1 | 1.5 | 3 | 4 |
| 16 | 4 | 3.5 | 3.5 | 3 | 2 | 2 | 1 | 1.5 | 3 | 4 |
| 18 | 4 | 3.5 | 3.5 | 3 | 2 | 2 | 1 | 1.5 | 3 | 4 |
| 20 | 4 | 4 | 3.5 | 3 | 2 | 2 | 1 | 1.5 | 3 | 4.5 |
| 24 | 4.5 | 4 | 3.5 | 3.5 | 2.5 | 2 | 1 | 1.5 | 3 | 4.5 |
| 30 | 4.5 | 4 | 3.5 | 3.5 | 2.5 | 2 | 1 | 1.5 | 3 | 4.5 |

**Design Criteria: Ambient Temp: 100°F, Relative Humidity 90%. Dew Point 97°F Wind Speed: 3 MPH, Jacket: (Painted Aluminum) 0.5 Emissivity**