



Piping Insulation

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Insulation and its ancillary components are major considerations in the design and installation of the plumbing and piping systems of modern buildings. Insulation is used for the following purposes:

- Retard heat or cooling temperature loss through pipe
- Eliminate condensation on piping
- Protect personnel by keeping the surface temperature of pipes low enough to touch
- Improve the appearance of pipe where aesthetics are important
- Protect pipe from abrasion or damage from external forces
- Reduce noise from a piping system

TERMINOLOGY

To ensure an understanding of the mechanism of heat, the following definitions are provided.

British thermal unit (Btu) The heat required to raise the temperature of 1 pound of water 1°F.

Conductance Also known as conductivity, the measurement of the flow of heat through an arbitrary thickness of material, rather than the 1-inch thickness used in thermal conductivity. (See also thermal conductivity.)

Convection The large-scale movement of heat through a fluid (liquid or gas). It cannot occur through a solid. The difference in density between hot and cold fluids produces a natural movement of heat.

Degree Celsius The measurement used in international standard (SI) units found by dividing the ice point and steam point of water into 100 divisions.

Degree Fahrenheit The measurement used in inch-pound (IP) units found by dividing the ice point and steam point of water into 180 divisions.

Heat A type of energy that is produced by the movement of molecules. More movement produces more heat. All heat (and movement) stops at absolute zero. It flows from a warmer body to a cooler body. It is calculated in such units as Btu, calories, or watt-hours.

Kilocalorie (kcal) The heat required to raise 1 kilogram of water 1°C.

Thermal conductivity The ability of a specific solid to conduct heat. This is measured in British thermal units per hour (Btuh) and is referred to as the k-factor. The standard used in the measurement is the heat that will

flow in one hour through a 1-inch-thick material, with a temperature difference of 1°F over an area of 1 square foot. The metric equivalent is watts per square meter per degree Kelvin ($W/m^2/^\circ K$). As the k-factor increases, so does the flow of heat.

Thermal resistance Abbreviated R, the reciprocal of the conductance value. (See conductance.)

Thermal transmittance Known as the U-factor, the rate of flow, measured in thermal resistance, through several different layers of materials taken together as a whole. It is measured in Btuh per square foot per degree Fahrenheit ($Btuh/ft^2/^\circ F$).

THE PHYSICS OF WATER VAPOR TRANSMISSION

Water vapor is present in the air at all times. A water vapor retarder does not stop the flow of water vapor. Rather, it serves as a means of controlling and reducing the rate of flow and is the only practical solution to the passage of water vapor. Its effectiveness depends on its location within the insulation system, which is usually as close to the outer surface of the insulation as practical. Water vapor has a vapor pressure that is a function of both temperature and relative humidity. The effectiveness of an insulation system is best when it is completely dry.

The water vapor transmission rate is a measure of water vapor diffusion into or through the total insulation system and is measured in perms. A perm is the weight of water, in grains, that is transmitted through 1 square foot of 1-inch-thick insulation in one hour. A generally accepted value of 0.10 perms is considered the maximum rate for an effective vapor retarder. A formula for the transmission of water vapor diffusing through insulation systems is given in Equation 5-1.

Equation 5-1

$$W = \mu A T \Delta \frac{P}{L}$$

where

W = Total weight of vapor transmitted, grains (7,000 grains = 1 pound of water)

μ = Permeability of insulation, grains/ft²/h/in. Hg ΔP /in.

A = Area of cross-section of the flow path, square feet

T = Time during which the transmission occurred, hours

ΔP = Difference of vapor pressure between ends of the flow path, inches of mercury (in. Hg)

L = Length of flow path, inches

TYPES OF INSULATION

Insulation manufacturers give their products different trade names. The discussions that follow use the generic names for the most often used materials in the plumbing and drainage industry. The insulation properties are based on the following conditions:

- All materials have been tested to ASTM, NFPA, and UL standards.
- The temperature at which the thermal conductivity and resistance were calculated is 75°F (24°C).

Insulation used for the chemical, pharmaceutical, and food-processing industries (for example) must be able to with-

stand repeated cleaning by various methods. This is provided by the application of the proper jacketing material (discussed later), which shall be resistant to organism growth, smooth and white, resistant to repeated cleaning by the method of choice by the owner, and nontoxic.

As with other building materials, insulation may contribute to a fire by either generating smoke (if the product is incombustible) or supporting combustion. Code limits for these factors have been established. These ratings are for complete insulation systems tested as a whole and not for individual components. The code requirements for insulation are a flame spread index of not more than 25 and a smoke-developed index of not more than 50. The standards governing the testing of materials for flame spread and smoke developed are ASTM E84, NFPA 255, and UL 723.

Fiberglass

Fiberglass insulation shall conform to ASTM C547. It is manufactured from glass fiber bonded with a phenolic resin. The chemical composition of this resin determines the highest temperature rating of this insulation. (Consult the manufacturer for exact figures.) This insulation is tested to fall below the index of 25 for flame spread and 50 for smoke developed. It has low water absorption and very limited to no combustibility. It has poor abrasion resistance.

Fiberglass is the most commonly used insulation for the retardation of heat loss from plumbing lines and equipment. The recommended temperature range is from 35°F to 800°F (1.8°C to 422°C), with ratings depending on the binder. It is available as pre-molded pipe insulation, boards, and blankets. Typical k-factors range from 0.22 to 0.26, and R values range from 3.8 to 4.5. Its density is about 3–5 pounds per cubic foot (48–80 kilograms per cubic meter).

Fiberglass by itself is not strong enough to stay on a pipe or piece of equipment, prevent the passage of water vapor, or present a finished appearance. Because of this, a covering or jacket must be used.

Elastomeric

Elastomeric insulation, commonly called rubber, shall conform to ASTM C534. This is a flexible, expanded foam made of closed-cell material manufactured from nitrile rubber and polyvinyl chloride resin. This insulation depends on its thickness to fall below a specific smoke-developed rating. All thicknesses have a flame spread index of 25. It can absorb 5 percent of its weight in water and has a perm rating of 0.10. Its density ranges between 3 pounds per cubic foot and 6 pounds per cubic foot.

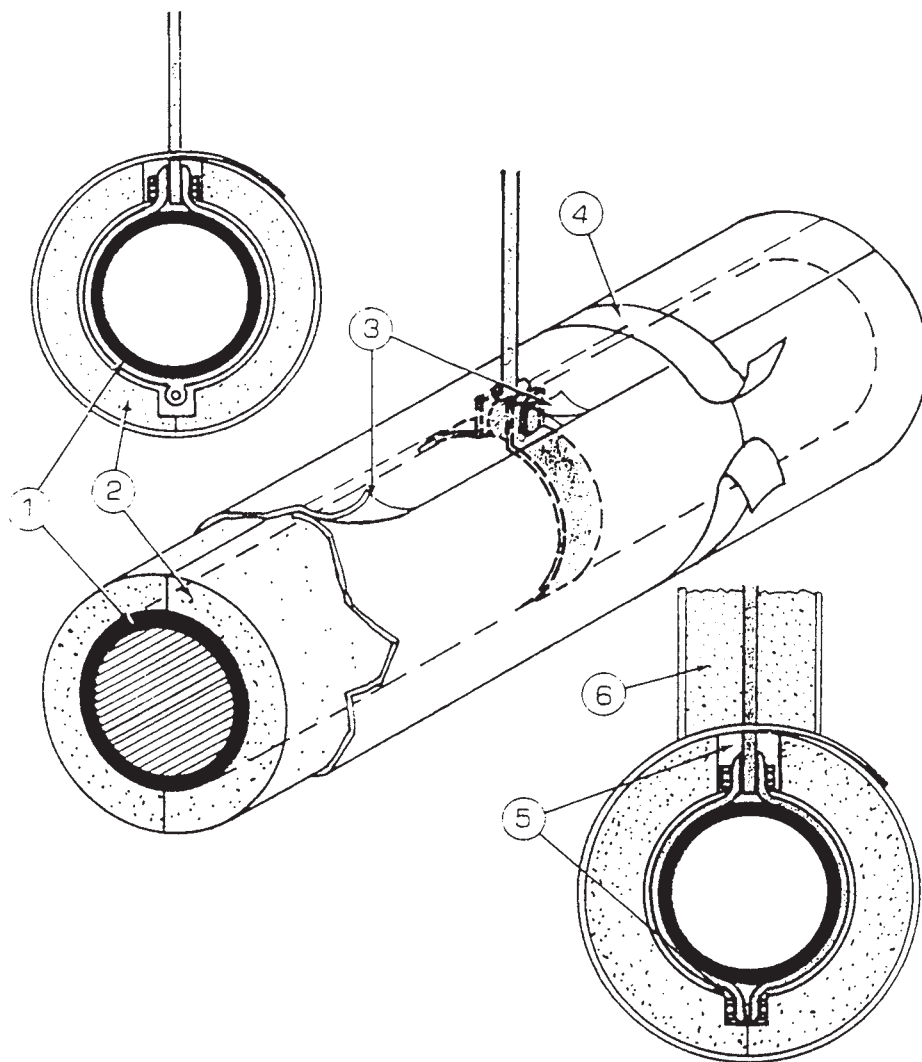


Figure 5-1 Insulating Around a Split Ring Hanger

1. Pipe
2. Insulation—shown with factory-applied, non-metal jacket
3. Overlap at longitudinal joints— cut to allow for hanger rod
4. Tape applied at butt joints— pipe covering section at hanger should extend a few inches beyond the hanger to facilitate proper butt joint sealing
5. Insulation altered to compensate for projections on split ring hangers—if insulation thickness is severely altered and left insufficient for high-temperature applications or condensation control, insulate with a sleeve of oversized pipe insulation
6. Insulation applied in like manner around rod on cold installations

Source: MICA

The recommended temperature range is from -297°F to 220°F (-183°C to 103°C). A typical k-factor is 0.27, and a typical R value is 3.6. It is recommended as preformed insulation for pipe sizes up to 6 inches (DN 150) in $\frac{1}{2}$ -inch, $\frac{3}{4}$ -inch, and 1-inch thicknesses. It is also available in 48-inch (1,200-mm) wide rolls and in sheet sizes of 36×48 inches ($900 \times 1,200$ mm). An adhesive must be used to seal the seams and joints and adhere the insulation to the equipment.

Rubber insulation can be painted without treatment. It is widely used in mechanical equipment rooms and pipe, and the ease of application makes it less costly. The recommended temperature range is from -297°F to 220°F (-183°C to 103°C)

Cellular Glass

Cellular glass shall conform to ASTM C552. This insulation is pure glass foam manufactured with hydrogen sulfide and has closed-cell air spaces. The smoke-developed rating is zero, and the flame spread is 5. The recommended application temperature is between -450°F and 450°F (-265°C and 230°C), with the adhesive used to secure the insulation to the pipe or equipment being the limiting factor. It has no water retention and poor surface abrasion resistance.

Cellular glass is rigid and strong and commonly used for high-temperature installations. It generally is manufactured in blocks and must be fabricated by the contractor to make insulation for pipes or equipment. A saw is used for cutting. It has a typical k-factor of 0.37 and an R value of 2.6. Its density is 8 pounds per cubic foot.

It is resistant to common acids and corrosive environments. It shall be provided with a jacket of some type.

Foamed Plastic

Foamed plastic insulation is a rigid, closed-cell product, which shall conform to the following standards depending on the material. Polyurethane shall conform to ASTM C591; polystyrene shall conform to ASTM C578; and polyethylene shall conform to ASTM C1427. It is made by the expansion of plastic beads or granules in a closed mold or using an extrusion process. The fire spread index varies among manufacturers, but its combustibility is high. Additives can be used to improve fire retardancy. It is available molded into boards or pre-molded into pipe insulation.

Foamed plastic is most commonly used in 3-inch or 4-inch thickness to insulate cryogenic piping. The recommended temperature range for installation is from cryogenic to 220°F (103°C). The density varies from 0.7 pound per cubic foot to 3 pounds per cubic foot. The k-factor varies between 0.32 and 0.20 depending on the density and age of the material. The average water absorption is 2 percent.

Calcium Silicate

Calcium silicate shall conform to ASTM C533. It is a rigid granular insulation composed of calcium silicate,

asbestos-free reinforcing fibers, and lime. This material has a k-factor of 0.38 and an R value of 2.

A mineral fiber commonly referred to as calsil, it is used for high-temperature work and does not find much use in the plumbing industry except as a rigid insert for installation at a hanger to protect the regular insulation from being crushed by the weight of the pipe.

Insulating Cement

Insulating cement is manufactured from fibrous and/or granular material and cement mixed with water to form a plastic substance. Sometimes referred to as mastic, it has typical k-factors ranging between 0.65 and 0.95 depending on the composition. It is well suited for irregular surfaces.

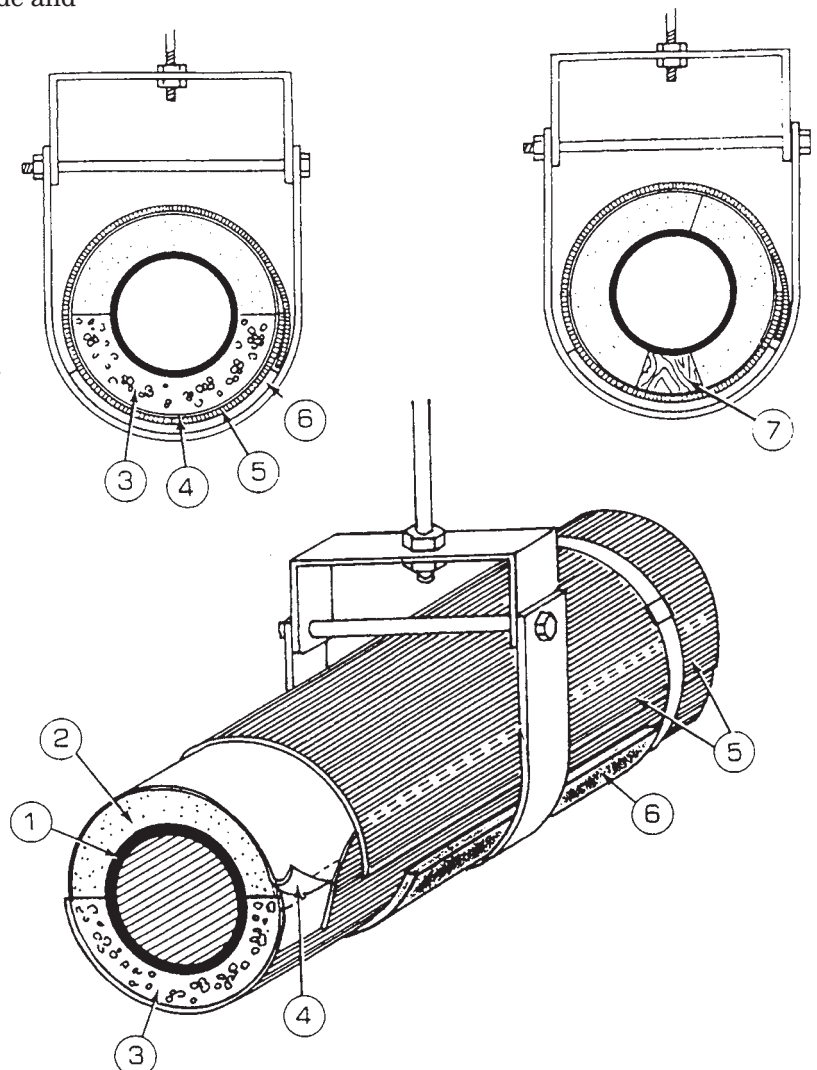


Figure 5-2 Insulating Around a Clevis Hanger

1. Pipe
2. Insulation—type specified for the line
3. High-density insulation insert—extend beyond the shield to facilitate proper butt joint sealing
4. Factory-applied vapor-retarder jacket securing two insulation sections together—cold application
5. Jacketing—field-applied metal shown
6. Metal shield
7. Wood block or wood dowel insert

Source: MICA

JACKET TYPES

A jacket is any material, except cement or paint, that is used to protect or cover insulation installed on a pipe or over equipment. It allows the insulation to function for a long period by protecting the underlying material and extending its service life. The jacket is used for the following purposes:

- As a vapor retarder to limit the entry of water into the insulation system
- As a weather barrier to protect the underlying insulation from exterior conditions
- To prevent mechanical abuse due to accidents
- Corrosion and additional fire resistance
- Appearance
- Cleanliness and disinfection

All-Service Jacket

Known as ASJ, the all-service jacket is a lamination of brown (kraft) paper, fiberglass cloth (skrim), and a metallic film. A vapor retarder also is included. This jacket also is called an FSK jacket because of the fiberglass cloth, scrim, and kraft paper. It most often is used to cover fiberglass insulation.

The fiberglass cloth is used to reinforce the kraft paper. The paper is generally a bleached, 30-pound (13.5-kg) material, which actually weighs 30 pounds per 30,000 square feet (2,790 m²). The metallic foil is aluminum. This complete jacket gives the fire rating for the insulation system.

The jacket is adhered to the pipe with either self-sealing adhesive or staples. The butt joint ends are sealed with adhesive, placed together, and then covered with lap strips during installation. Staples are used when the surrounding conditions are too dirty or corrosive to use self-sealing material. The staple holes shall be sealed with adhesive.

Aluminum Jacket

Aluminum jackets shall conform to ASTM B209. They are manufactured as corrugated or smooth and are available in various thicknesses ranging from 0.010 inch to 0.024 inch, with 0.016 inch being the most common. The corrugated version is used where expansion and contraction of the piping may be a problem. Aluminum jackets also are made in various tempers and alloys. A vapor retarder material can be applied to protect the aluminum from any corrosive ingredient in the insulation. Fittings are fabricated in the shop.

Aluminum jackets may be secured by one of three methods: by straps on 9-inch (180-mm) centers, by a proprietary S or Z shape, or by sheet metal screws.

Stainless Steel Jacket

Stainless steel jackets shall conform to ASTM A240. They are manufactured as corrugated or smooth and are available in various thicknesses ranging from 0.010 inch to 0.019 inch, with 0.016 inch being the most common. They are also available in various alloy types conforming to ASTM A304 and can be obtained in different finishes. A vapor retarder material can be applied, although it is not required for corrosive environments except where chlorine or fluorides are present.

Stainless steel jackets are used for hygienic purposes and are adhered in a manner similar to that used for aluminum.

Plastic and Laminates

Plastic jackets are manufactured from polyvinyl chloride (PVC), polyvinylidene fluoride (PVDF), acrylonitrile butadiene styrene (ABS), polyvinyl acetate (PVA), and acrylics. Thicknesses range from 3 mils to 35 mils. The local code authority shall be consulted prior to their use.

Table 5-1 Heat Loss in Btuh/ft Length of Fiberglass Insulation, ASJ Cover 150°F Temperature of Pipe

Horizontal																								
NPS	½		¾		1		1¼		1½		2		2½		3		4		5		6		8	
THK	HL																							
BARE	36		44		54		67		75		92		110		131		165		200		235		299	
½"	10	92	10	90	13	93	20	98	18	94	20	93	23	94	30	95	36	95	43	95	53	97	68	97
1"	7	86	8	87	9	86	11	88	11	87	13	87	15	88	18	88	22	88	27	89	32	89	38	89
1½"	5	84	6	84	7	84	8	84	9	85	10	85	10	84	14	85	17	86	20	86	23	86	28	8
2"	5	82	5	83	6	83	7	83	7	83	9	83	9	83	11	84	14	84	16	84	18	84	23	85

Vertical																								
	½		¾		1		1¼		1½		2		2½		3		4		5		6		8	
THK	HL																							
BARE	32		40		49		61		69		84		100		120		152		185		217		277	
½"	9	92	10	90	13	93	19	99	18	95	20	94	23	94	30	96	35	96	43	96	52	97	67	98
1"	7	86	8	87	9	86	11	88	11	87	13	88	15	88	18	89	22	89	26	89	31	90	38	89
1½"	5	84	6	84	7	84	8	84	9	85	10	85	10	84	14	86	16	86	20	86	23	87	28	8
2"	5	83	5	83	6	83	7	83	7	83	9	83	9	83	11	84	14	84	16	85	18	85	23	85

Source: Courtesy of Owens/Corning.

Notes: 80° ambient temperature,

0 wind velocity,

0.85 bare surface emittance,

0.90 surface emittance

HL = heat loss (BTU/h/ft length)

ST = surface temperature (°F)

Bare = bare pipe, iron pipe size

THK = thickness

Table 5-2 Heat Loss from Piping

Insulation Type	Insulation Factor	Heat Loss per Inch Thickness, Based on K Factor @ 50°F Mean Temp. (Btu/h • °F • ft ²)
Glass fiber (ASTM C547)	1.00	0.25
Calcium silicate (ASTM C533)	1.50	0.375
Cellular glass (ASTM C552)	1.60	0.40
Rigid cellular urethane (ASTM C591)	0.66	0.165
Foamed elastomer (ASTM C534)	1.16	0.29
Mineral fiber blanket (ASTM C553)	1.20	0.30
Expanded perlite (ASTM C610)	1.50	0.375

Insulation Thickness (in.)	ΔT, °F	IPS													
		½	¾	1	1¼	1½	2	2½	3	4	6	8	10	12	
		Tubing Size (in.)													
		¾	1	1¼	1½										
0.5	10	0.5	0.6	0.7	0.8	0.9	1.1	1.3	1.5	1.8	2.6	3.3	4.1	4.8	
	50	2.5	2.9	3.5	4.1	4.8	5.5	6.5	7.7	9.6	13.5	17.2	21.1	24.8	
	100	5.2	6.1	7.2	8.6	9.9	11.5	13.5	15.9	19.9	28.1	35.8	43.8	51.6	
	150	8.1	9.5	11.2	13.4	15.5	17.9	21.0	24.8	31.9	43.8	55.7	68.2	80.2	
	200	11.2	13.1	15.5	18.5	21.4	24.7	29.0	34.3	42.7	60.4	76.9	94.1	110.7	
	250	14.6	17.1	20.2	24.1	27.9	32.2	37.8	44.7	55.7	78.8	100.3	122.6	144.2	
1.0	10	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8	1.0	1.4	1.8	2.2	2.6	
	50	1.6	1.9	2.2	2.5	2.9	3.2	3.7	4.4	5.4	7.4	9.4	11.4	13.4	
	100	3.4	3.9	4.5	5.2	5.9	6.8	7.8	9.1	11.2	15.5	19.5	23.8	27.8	
	150	5.3	6.1	7.0	8.2	9.3	10.5	12.2	14.2	17.4	24.1	30.4	37.0	43.3	
	200	7.4	8.4	9.7	11.3	12.8	14.6	16.8	19.6	24.0	33.4	42.0	51.2	59.9	
	250	9.6	11.0	12.6	14.8	16.7	19.0	22.0	25.6	31.4	43.6	54.9	66.9	78.2	
1.5	10	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.8	1.0	1.3	1.4	1.8	
	50	1.3	1.5	1.7	1.9	2.2	2.4	2.8	3.2	3.9	5.3	6.6	8.0	9.3	
	100	2.7	3.1	3.5	4.0	4.5	5.1	5.8	6.7	8.1	11.1	13.8	16.7	19.5	
	150	4.3	4.8	5.5	6.3	7.1	7.9	9.1	10.4	12.6	17.2	21.5	26.0	30.3	
	200	5.9	6.7	7.6	8.7	9.8	11.0	12.5	14.5	17.5	23.8	29.7	36.0	41.9	
	250	7.8	8.7	9.9	11.4	12.8	14.4	16.4	18.9	22.8	31.1	38.9	47.1	54.8	
2.0	10	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.6	0.8	1.0	1.2	1.4	
	50	1.1	1.3	1.4	1.6	1.8	2.0	2.3	2.6	3.1	4.2	5.2	6.3	7.3	
	100	2.4	2.7	3.0	3.4	3.8	4.2	4.8	5.5	6.5	8.8	10.9	13.1	15.2	
	150	3.7	4.2	4.7	5.3	5.9	6.6	7.5	8.5	10.2	13.7	17.0	20.4	23.6	
	200	5.2	5.8	6.5	7.4	8.2	9.1	10.3	11.8	14.1	19.0	23.5	28.2	32.7	
	250	6.8	7.5	8.5	9.6	10.7	11.9	13.5	15.4	18.5	24.8	30.7	36.9	42.7	
2.5	10	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.7	0.8	1.0	1.2	
	50	1.0	1.1	1.3	1.4	1.6	1.8	2.0	2.3	2.7	3.6	4.4	5.2	6.0	
	100	2.2	2.4	2.7	3.0	3.3	3.7	4.1	4.7	5.6	7.7	9.1	10.9	12.6	
	150	3.4	3.7	4.2	4.7	5.2	5.8	6.5	7.3	8.7	11.5	14.2	17.0	19.6	
	200	4.7	5.2	5.8	6.5	7.2	8.0	9.0	10.2	12.1	16.0	19.6	23.5	27.1	
	250	6.1	6.8	7.5	8.5	9.4	10.4	11.7	13.3	15.8	20.9	25.7	30.7	35.4	
3.0	10	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.5	0.6	0.7	0.9	1.0	
	50	1.0	1.1	1.2	1.3	1.4	1.6	1.8	2.0	2.4	3.1	3.8	4.5	5.2	
	100	2.0	2.2	2.4	2.7	3.0	3.3	3.7	4.2	4.9	6.5	7.9	9.4	10.8	
	150	3.1	3.4	3.8	4.3	4.7	5.2	5.8	5.6	7.7	10.1	12.3	14.7	16.8	
	200	4.3	4.8	5.3	5.9	6.5	7.2	8.0	9.0	10.7	14.0	17.0	20.3	23.3	
	250	5.7	6.2	6.9	7.7	8.5	9.4	10.5	11.8	13.9	18.3	22.3	26.5	30.5	

Laminates are manufactured as a composite that is alternating layers of foil and polymer. Thicknesses range from 3 to 25 mils. The local code authority shall be consulted prior to their use.

Both are adhered by the use of an appropriate adhesive.

Wire Mesh

Wire mesh is available in various wire diameters and widths. Materials for manufacture are Monel, stainless steel, and Inconel. Wire mesh is used where a strong, flexible covering

that can be removed easily is needed. It is secured with lacing hooks or stainless steel wire that must be additionally wrapped with tie wire or metal straps.

Lagging

Lagging is the covering of a previously insulated pipe or piece of equipment with a cloth or fiberglass jacket. It is used where appearance is the primary consideration, since this type of jacket offers little or no additional insulation protection. This

material also is used as a combination system that serves as a protective coat and adhesive.

This jacket typically is secured to the insulation with the use of lagging adhesive and/or sizing. It is available in a variety of colors and may eliminate the need for painting.

INSTALLATION TECHNIQUES

Insulation for Valves and Fittings

The fittings and valves on a piping system require specially formed or made-up sections of insulation to complete the installation.

One type of insulation is the pre-formed type that is manufactured by specific size and shape to fit over any particular fitting or valve. Such insulation is available in two sections that are secured with staples, adhesive, or pressure-sensitive tape depending on the use of a vapor retarder. This is the quickest method of installation, but the most costly.

Another system uses a pre-formed plastic jacket the exact size and shape of the fitting or valve. A fiberglass blanket or sheet is cut to size and wrapped around the bare pipe, and then the jacket is placed over the insulation. The exposed edges are tucked in, and the jacket is secured with special tacks with a barb that prevents them from pulling apart. The ends are sealed with pressure-sensitive tape.

For large piping, it is common to use straight lengths of fiberglass by mitering the ends and securing them with a fiberglass jacket (lagging).

Insulation for Tanks

Where fiberglass is specified, tanks are insulated using 2×4-foot boards in the thickness required. The boards are placed on the tank in a manner similar to brick laying. They are secured with metal bands. Wire is placed over the bands as a foundation for insulating cement applied over the tank to give a finished appearance.

Where rubber is specified, the tank is coated with adhesive, and the rubber sheets are placed on the tank. The edges are coated with adhesive to seal it. Painting is not required.

Insulation Around Pipe Supports

As the installation on a project progresses, a contractor must contend with different situations regarding the vapor retarder. Since the insulation system selected shall be protected against the migration of water vapor into the insulation, the integrity of the vapor retarder must be maintained. Where a hanger is installed directly on the pipe, the insulation must be placed over both the pipe and the hanger. Figure 5-1 illustrates a split-ring hanger attached directly on the pipe.

Since low-density insulation is the type most often used, a situation arises wherein the primary considerations are keeping the vapor retarder intact and preventing the weight of the pipe from crushing the insulation. Figure 5-2 illustrates several high-density insert solutions for a clevis hanger supporting an insulated pipe.

The jacketing method shown in both figures can be used interchangeably with any type of insulation for which it is suited.

Table 5-3 Insulation Thickness - Equivalent Thickness (in.)

DN	NPS	½		1		1½		2		2½		3	
		L ₁	A	L ₁	A	L ₁	A	L ₁	A	L ₁	A	L ₁	A
15	½	0.76	0.49	1.77	0.75	3.12	1.05	4.46	1.31				
20	¾	0.75	0.56	1.45	0.75	2.68	1.05	3.90	1.31				
25	1	0.71	0.62	1.72	0.92	2.78	1.18	4.02	1.46	—	—	—	—
32	1¼	0.63	0.70	1.31	0.92	2.76	1.31	3.36	1.46				
40	1½	0.60	0.75	1.49	1.05	2.42	1.31	4.13	1.73				
50	2	0.67	0.92	1.43	1.18	2.36	1.46	3.39	1.73	4.43	1.99	—	—
65	2½	0.66	1.05	1.38	1.31	2.75	1.73	3.71	1.99	4.73	2.26		
80	3	0.57	1.18	1.29	1.46	2.11	1.73	2.96	1.99	3.88	2.26	4.86	2.52
90	3½	0.92	1.46	1.67	1.73	2.46	1.99	3.31	2.26	4.22	2.52	5.31	2.81
100	4	0.59	1.46	1.28	1.73	2.01	1.99	2.80	2.26	3.65	2.52	4.68	2.81
115	4½	0.94	1.74	1.61	1.99	2.35	2.26	3.15	2.52	4.11	2.81	5.02	3.08
125	5	0.58	1.74	1.20	1.99	1.89	2.26	2.64	2.52	3.54	2.81	4.40	3.08
150	6	0.54	2.00	1.13	2.26	1.79	2.52	2.60	2.81	3.36	3.08	4.17	3.34
	7	—	—	1.11	2.52	1.84	2.81	2.54	3.08	3.27	3.34	4.25	3.67
200	8	—	—	1.18	2.81	1.81	3.08	2.49	3.34	3.39	3.67	4.15	3.93
	9	—	—	1.17	3.08	1.79	3.34	2.62	3.67	3.32	3.93	4.06	4.19
250	10	—	—	1.09	3.34	1.85	3.67	2.50	3.93	3.18	4.19	3.90	4.45
300	12	—	—	1.22	3.93	1.82	4.19	2.45	4.45	3.10	4.71	3.79	4.97
350	14	—	—	1.07	4.19	1.65	4.45	2.26	4.71	2.90	4.97	3.57	5.24
400	16	—	—	1.06	4.71	1.63	4.97	2.23	5.24	2.86	5.50	3.50	5.76
450	18	—	—	1.05	5.24	1.62	5.50	2.21	5.76	2.82	6.02	3.45	6.28
500	20	—	—	1.05	5.76	1.61	6.02	2.19	6.28	2.79	6.54	3.41	6.81
600	24	—	—	1.04	6.81	1.59	7.07	2.16	7.33	2.74	7.59	3.35	7.85

Source: Owens/Corning.

DN = nominal diameter

NPS = nominal pipe size

L₁ = equivalent thickness (in.)

L₁ = r₂ ln (r₂/r₁)

where

r₁ = inner radius of insulation (in.)

r₂ = outer radius of insulation (in.)

ln = log to the base e (natural log)

A = square feet of pipe insulation surface per lineal foot of pipe

SELECTING INSULATION THICKNESS

Selecting the proper insulation thickness is affected by the reason for using insulation:

1. Controlling heat loss from piping or equipment
2. Condensation control
3. Personnel protection
4. Economics

Controlling Heat Loss

Increased concern about conservation and energy use has resulted in the insulation of piping to control heat loss becoming one of the primary considerations in design. Heat loss is basically an economic consideration, since the lessening of heat loss produces a more cost-efficient piping system. The proper use of insulation can have dramatic results.

The insulation installed on domestic hot water, hot water return, and chilled drinking water systems is intended to minimize heat loss from the water. Since fiberglass insulation is the type most often used, Table 5-1 is provided to give the heat loss through vertical and horizontal piping

Table 5-4 Dewpoint Temperature

Dry Bulb Temp. (°F)	Percent Relative Humidity																		
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
5	-35	-30	-25	-21	-17	-14	-12	-10	-8	-6	-5	-4	-2	-1	1	2	3	4	5
10	-31	-25	-20	-16	-13	-10	-7	-5	-3	-2	0	2	3	4	5	7	8	9	10
15	-28	-21	-16	-12	-8	-5	-3	-1	1	3	5	6	8	9	10	12	13	14	15
20	-24	-16	-11	-8	-4	-2	2	4	6	8	10	11	13	14	15	16	18	19	20
25	-20	-15	-8	-4	0	3	6	8	10	12	15	16	18	19	20	21	23	24	25
30	-15	-9	-3	2	5	8	11	13	15	17	20	22	23	24	25	27	28	29	30
35	-12	-5	1	5	9	12	15	18	20	22	24	26	27	28	30	32	33	34	35
40	-7	0	5	9	14	16	19	22	24	26	28	29	31	33	35	36	38	39	40
45	-4	3	9	13	17	20	23	25	28	30	32	34	36	38	39	41	43	44	45
50	-1	7	13	17	21	24	27	30	32	34	37	39	41	42	44	45	47	49	50
55	3	11	16	21	25	28	32	34	37	39	41	43	45	47	49	50	52	53	55
60	6	14	20	25	29	32	35	39	42	44	46	48	50	52	54	55	57	59	60
65	10	18	24	28	33	38	40	43	46	49	51	53	55	57	59	60	62	63	65
70	13	21	28	33	37	41	45	48	50	53	55	57	60	62	64	65	67	68	70
75	17	25	32	37	42	46	49	52	55	57	60	62	64	66	69	70	72	74	75
80	20	29	35	41	46	50	54	57	60	62	65	67	69	72	74	75	77	78	80
85	23	32	40	45	50	54	58	61	64	67	69	72	74	76	78	80	82	83	85
90	27	36	44	49	54	58	62	66	69	72	74	77	79	81	83	85	87	89	90
95	30	40	48	54	59	63	67	70	73	76	79	82	84	86	88	90	91	93	95
100	34	44	52	58	63	68	71	75	78	81	84	86	88	91	92	94	96	98	100
110	41	52	60	66	71	77	80	84	87	90	92	95	98	100	102	104	106	108	110
120	48	60	68	74	79	85	88	92	96	99	102	105	109	109	112	114	116	118	120
125	52	63	72	78	84	89	93	97	100	104	107	109	111	114	117	119	121	123	125

Table 5-5 Insulation Thickness to Prevent Condensation, 50°F Service Temperature and 70°F Ambient Temperature
Relative Humidity (%)

DN	Nom. Pipe Size (in.)	20			50			70			80			90		
		THK	HG	ST	THK	HG	ST	THK	HG	ST	THK	HG	ST	THK	HG	ST
15	0.50	Condensation control not required for this condition			0.5	2	66	0.5	2	66	0.5	2	66	1.0	2	68
20	0.75				0.5	2	67	0.5	2	67	0.5	2	67	0.5	2	67
25	1.00				0.5	3	66	0.5	3	66	0.5	3	66	1.0	2	68
32	1.25				0.5	3	66	0.5	3	66	0.5	3	66	1.0	3	67
40	1.50				0.5	4	65	0.5	4	65	0.5	4	65	1.0	3	67
50	2.00				0.5	5	66	0.5	5	66	0.5	5	66	1.0	3	67
65	2.50				0.5	5	65	0.5	5	65	0.5	5	65	1.0	4	67
75	3.00				0.5	7	65	0.5	7	65	0.5	7	65	1.0	4	67
90	3.50				0.5	8	65	0.5	8	65	0.5	8	65	1.0	4	68
100	4.00				0.5	8	65	0.5	8	65	0.5	8	65	1.0	5	67
125	5.00				0.5	10	65	0.5	10	65	0.5	10	65	1.0	6	67
150	6.00				0.5	12	65	0.5	12	65	0.5	12	65	1.0	7	67
200	8.00				1.0	9	67	1.0	9	67	1.0	9	67	1.0	9	67
250	10.00				1.0	11	67	1.0	11	67	1.0	11	67	1.0	11	67
300	12.00				1.0	12	67	1.0	12	67	1.0	12	67	1.0	12	67

Source: Courtesy Certainteed.

Notes: 25 mm = 1 in.

THK = Insulation thickness (in.).

HG = Heat gain/lineal foot (pipe) 28 ft (flat) (Btu). ST = Surface temperature (°F).

as well as the heat loss through bare pipe. Table 5-2 is given for piping intended to be installed outdoors.

When calculating the heat loss from round surfaces such as a pipe, the plumbing engineer should remember that the inside surface of the insulation has a different diameter than the outside. Therefore, a means must be found to determine the equivalent thickness that shall be used. This is done by the use of Table 5-3. To read this table, enter with the

actual pipe size and insulation thickness, and then find the equivalent thickness of the insulation.

Software endorsed by the U.S. Department of Energy and distributed by the North American Insulation Manufacturers Association (NAIMA) that will calculate heat loss, condensation control, and environmental emissions is available at pipeinsulation.org.

**Table 5-6 Insulation Thickness for Personnel Protection,
120°F Maximum Surface Temperature, 80°F Ambient Temperature**

Service Temperature

Nom. Pipe Size (in.)	250				350				450				550			
	TH	HL		ST	TH	HL		ST	TH	HL		ST	TH	HL		ST
		LF	SF			LF	SF			LF	SF			LF	SF	
0.50	0.5	25	51	109	1.0	30	40	104	1.0	48	64	118	1.5	55	52	113
0.75	0.5	25	41	104	0.5	42	68	120	1.5	45	43	107	1.5	64	61	118
1.00	0.5	34	55	112	1.0	37	40	105	1.0	60	66	120	1.5	69	58	117
1.25	0.5	37	49	109	1.0	47	51	112	1.5	55	42	107	1.5	77	59	118
1.50	0.5	46	61	117	1.0	48	46	109	1.5	62	47	110	2.0	70	40	106
2.00	0.5	50	55	114	1.0	56	47	110	1.5	70	48	111	2.0	84	48	112
2.50	0.5	59	56	115	1.5	45	26	97	1.5	72	41	107	1.5	102	59	119
3.00	0.5	75	64	120	1.0	76	52	114	1.5	93	53	115	2.0	110	55	117
3.50	1.0	43	25	96	1.0	71	41	107	1.5	93	46	111	2.0	112	49	113
4.00	0.5	89	61	119	1.0	90	52	114	1.5	112	56	117	2.0	131	58	119
5.00	1.0	67	33	102	1.0	110	55	117	1.5	134	59	120	2.5	131	46	112
6.00	1.0	79	35	103	1.0	130	57	119	2.0	124	44	110	2.5	150	48	114
8.00	1.0	95	33	103	1.0	157	55	118	2.0	153	45	112	2.5	177	48	114
10.00	1.0	121	36	105	1.5	136	37	106	2.0	179	45	112	2.5	215	51	117
12.00	1.0	129	32	103	1.0	212	54	118	2.0	207	46	113	2.5	248	52	118

Source: Certainteed.

Notes: TH = Thickness of insulation (in.)

HL = heat loss (Btu/h)

LF = Heat loss per lineal foot of pipe (Btu/h)

SF = Heat loss per square foot of outside insulation surface (Btu/h)

ST = Surface temperature of insulation (°F)

Table 5-7 Time for Dormant Water to Freeze

Fiberglass Insulation

Pipe or Tubing Size (in.)	Air Temp., °F (°C)	Water Temp., °F (°C)	Insulation Thickness, in. (mm)	Time to 32°F (0°C) DORMANT water (h)	Time to 32°F (0°C) Solid Ice (h) ^a	Flow ^b
5/8 OD CT	-10 (-23.3)	50 (10)	0.66 (N¾) (19.1)	0.30	3.10	0.33
1½ OD CT	-10 (-23.3)	50 (10)	0.74 (N¾) (19.1)	0.75	8.25	0.44
1½ OD CT	-10 (-23.3)	50 (10)	0.79 (N¾) (19.1)	1.40	14.75	0.57
3½ OD CT	-10 (-23.3)	50 (10)	0.88 (N¾) (19.1)	3.5	37.70	0.83
1 IPS	-10 (-23.3)	50 (10)	0.76 (N¾) (19.1)	0.75	8.25	0.48
2 IPS	-10 (-23.3)	50 (10)	0.85 (N¾) (19.1)	2.10	22.70	0.67
3 IPS	-10 (-23.3)	50 (10)	0.89 (N¾) (19.1)	3.60	38.40	0.90
5 IPS	-10 (-23.3)	50 (10)	0.95 (N¾) (19.1)	6.95	73.60	1.25

Foamed Plastic Insulation

Pipe or Tubing Size (in.)	Air Temp., °F (°C)	Water Temp., °F (°C)	Insulation Thickness, in. (mm)	Time to 32°F (0°C) DORMANT water (h)	Time to 32°F (0°C) Solid Ice (h) ^a	Flow ^b
5/8 OD CT	-10 (-23.3)	50 (10)	1 (25.4)	0.60	6.20	0.16
1½ OD CT	-10 (-23.3)	50 (10)	1 (25.4)	1.30	13.70	0.26
1½ OD CT	-10 (-23.3)	50 (10)	1 (25.4)	2.35	24.75	0.32
3½ OD CT	-10 (-23.3)	50 (10)	1 (25.4)	5.55	58.65	0.52
1 IPS	-10 (-23.3)	50 (10)	1 (25.4)	1.50	15.75	0.25
2 IPS	-10 (-23.3)	50 (10)	1 (25.4)	3.80	40.15	0.39
3 IPS	-10 (-23.3)	50 (10)	1 (25.4)	6.05	64.20	0.53
5 IPS	-10 (-23.3)	50 (10)	1 (25.4)	11.15	118.25	0.78

^a No way to calculate slush. 32°F (0°C) ice value higher due to heat of fusion.

^b Flow is expressed as gal/h/ft of pipe (12.4 Ufr-m).

Example: For 100 ft. (30.5m) pipe run, multiply value shown by 100. This is the minimum continuous flow to keep water from freezing.

OD CT = outside diameter, copper tube

IPS = iron pipe size

Condensation Control

As mentioned, water vapor in the air condenses on a cold surface if the temperature of the cold surface is at or below the dewpoint. If the temperature is above the dewpoint, condensation does not form. The purpose of a vapor retarder is to minimize or eliminate such condensation. For this to be accomplished, the joints and overlaps must be sealed tightly. This is done through one of three methods:

1. Rigid jackets such as metallic or plastic
2. Membranes such as laminated foils
3. Mastics applied over the pipe, either emulsion or solvent type

Table 5-4 shows the dry-bulb dewpoint temperature at which condensation forms. Table 5-5 is provided to indicate the thickness of fiberglass insulation needed to prevent condensation with water at 50°F (10°C).

Personnel Protection

When hot water flows through an uninsulated piping system, it is usually at a temperature that may scald any person touching the pipe. Insulation is used to lower the surface temperatures of hot water pipes to prevent such harm. A surface temperature of 120°F (49°C) has been shown to not burn a person who touches the pipe. Table 5-6 provides the thickness of fiberglass insulation and the surface temperature of the insulation. The thicknesses shown in this table should be compared with those shown in Table 5-1 or 5-2 to see which thickness is greater. The larger thickness should be used.

Economics

The two economic factors involved are the cost of the insulation and the cost of energy. To calculate the energy savings in financial terms, the following are needed: service temperature of the surface, pipe size or surface dimensions, Btu difference between the air and the surface (linear feet or square feet), efficiency of heating equipment, annual operating hours, and the cost of fuel.

If the plumbing designer wishes to make an economic comparison among various insulation systems, many formulas and computer programs are available for the purpose. Discussion of these methods is beyond the scope of this chapter.

FREEZE PROTECTION

No amount of insulation can prevent the freezing of water (or sewage) in a pipeline that remains dormant over a long period. Table 5-7 is provided as a direct reading table for estimating the time it takes for dormant water to freeze. For some installations, it is not possible for the water to remain dormant. If the water is flowing, as it does in a drainage line, use Figure 5-3, a nomogram that gives the temperature drop of flowing water. If the contents cannot be prevented from freezing, the plumbing engineer can add hot water to raise the temperature, heat trace the line, or provide sufficient velocity to keep the contents from freezing.

To calculate the flow of water in a line to prevent freezing, use Equation 5-2.

Equation 5-2

$$\text{gpm} = \frac{A_1 \times A_2 \times (0.5\text{TW} - \text{TA} + 16)}{40.1 \text{ D}^2 (\text{TW} - 32)}$$

where

gpm = Flow rate, gallons per minute

A_1 = Pipe flow area, square feet

A_2 = Exposed pipe surface area, square feet

TW = Water temperature, °F

TA = Lowest air temperature, °F

D = Inside diameter of pipe, feet

INSULATION DESIGN CONSIDERATIONS

Following are some general items to consider when designing the insulation for a plumbing system.

1. Insulation attenuates sound from the flow of pipe contents. Where sound is a problem, such as in theaters, adding a mass-filled vinyl layer over the insulation can lessen the sound.
2. Protecting health and safety when storing and handling insulation and/or jacketing materials can be alleviated by proper adherence to established safe storage and handling procedures.
3. The rate of expansion affects the efficiency of the insulation over a long period. The difference between the expansion of insulation and the expansion of the pipe eventually leads to gaps after numerous flexings.
4. Protect the insulation against physical damage by adding a strong jacket or delaying installation on a piping system. It has been found that workmen walking on the pipe pose the greatest danger.
5. If the insulation is to be installed in a corrosive atmosphere, the proper jacket shall be installed to withstand the most severe conditions.
6. Union regulations should be reviewed to ensure that the insulation contractor installs a jacket. Some metal jackets above a certain thickness are installed by the general contractor.
7. Space conditions may dictate the use of one insulation system over another to fit in a confined space.

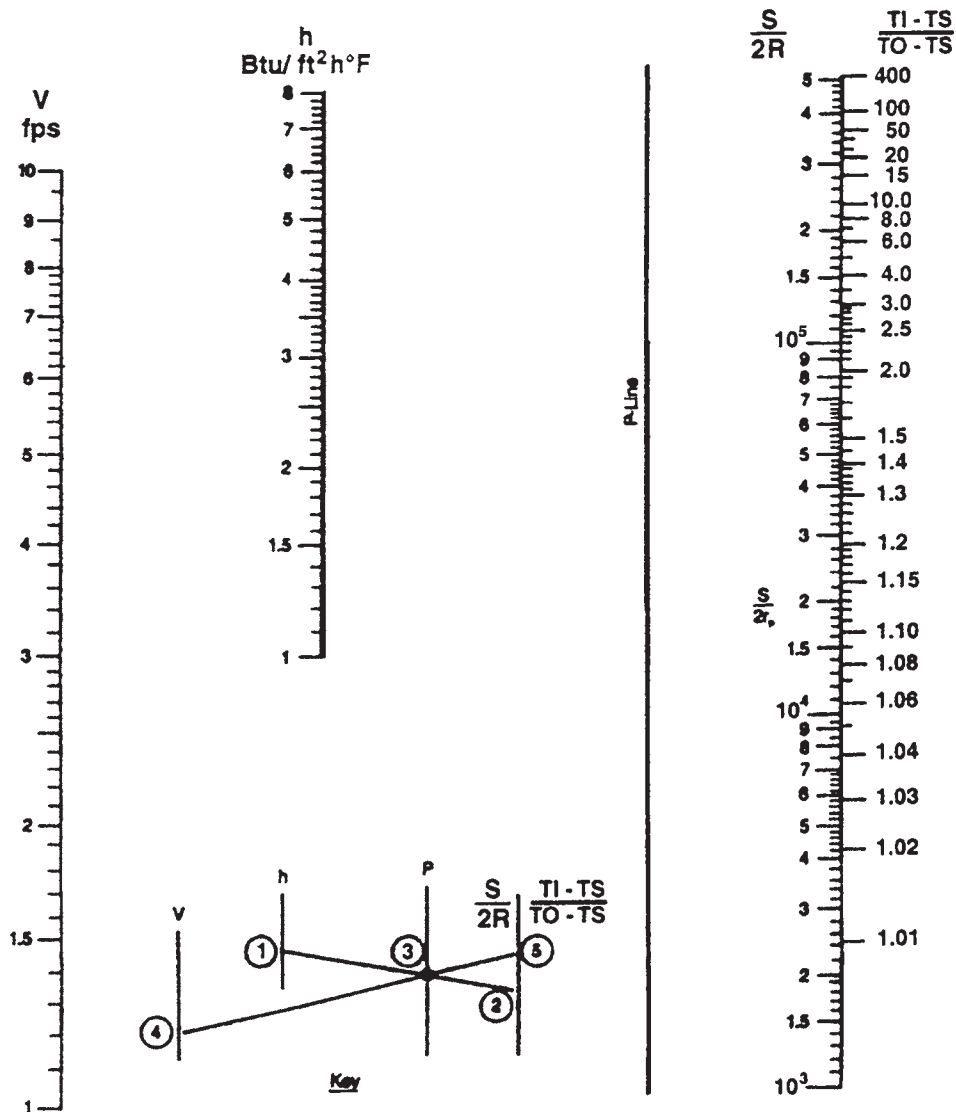


Figure 5-3 Temperature Drop of Flowing Water in a Pipeline

ASPE Read, Learn, Earn Continuing Education

You may submit your answers to the following questions online at aspe.org/readlearnearn. If you score 90 percent or higher on the test, you will be notified that you have earned 0.1 CEU, which can be applied toward CPD renewal or numerous regulatory-agency CE programs. (Please note that it is your responsibility to determine the acceptance policy of a particular agency.) CEU information will be kept on file at the ASPE office for three years.

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Expiration date: Continuing education credit will be given for this examination through **February 28, 2014**.

CE Questions — "Piping Insulation" (CEU 196)

1. Insulation is used to _____.
 - a. eliminate condensation on piping
 - b. reduce piping system noise
 - c. retard heat loss through pipe
 - d. all of the above
2. The k-factor refers to a solid's _____.
 - a. thermal transmittance
 - b. thermal conductivity
 - c. thermal resistance
 - d. conductance
3. The maximum recommended water vapor transmission rate for an effective vapor retarder is _____.
 - a. 0.001 perm
 - b. 0.01 perm
 - c. 0.1 perm
 - d. 1 perm
4. What is the maximum code-required flame spread index for insulation?
 - a. 20
 - b. 25
 - c. 50
 - d. 55
5. What insulation is most commonly used to retard heat loss from plumbing lines and equipment?
 - a. rubber
 - b. foamed plastic
 - c. cellular glass
 - d. fiberglass
6. What insulation is most commonly used to insulate cryogenic piping?
 - a. rubber
 - b. foamed plastic
 - c. cellular glass
 - d. fiberglass
7. Which type of jacket is most often used to cover fiberglass insulation?
 - a. aluminum
 - b. stainless steel
 - c. all service
 - d. plastic
8. A corrugated _____ jacket is used where expansion and contraction of the piping may be a problem.
 - a. aluminum
 - b. stainless steel
 - c. all service
 - d. plastic
9. _____ is used where a strong, flexible covering that can be removed easily is needed.
 - a. lagging
 - b. wire mesh
 - c. all-service jacket
 - d. fiberglass jacket
10. Condensation control is not needed at _____ relative humidity at 50°F service temperature and 70°F ambient temperature.
 - a. 20 percent
 - b. 50 percent
 - c. 70 percent
 - d. 80 percent
11. What has become one of the primary considerations for insulating pipe?
 - a. protecting personnel
 - b. controlling heat loss
 - c. controlling condensation
 - d. none of the above
12. The rate of _____ affects the efficiency of insulation over a long period.
 - a. heat loss
 - b. thermal conductivity
 - c. expansion
 - d. permeability