# INDUSTRIAL INSULATION

for Systems Operating Above Ambient Temperature

**U.S. Department of Energy**
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## Background

This bulletin was prepared to provide readily accessible information about the value to industry of thermal insulation on piping and flat surfaces wherever operating temperatures are above surrounding ambient conditions. Installing thermal insulation can dramatically reduce the thermal energy (heat) lost through these surfaces. Cutting such losses is an economically sound measure in energy conservation programs, and is especially cost effective in facilities where lost heat has value. In addition, for systems operating above 200$^0$F, insulation contributes to worker safety.

Insulation cannot be applied to pipes or flat surfaces without care because it will change temperature distribution within a thermal system by increasing operating temperatures of pipes and walls. The changed temperature distribution regime must be taken into account especially in the case of temperature sensitive processes or materials.

The tables contained in this bulletin offer a tool for quickly estimating possible savings by applying thermal insulation. The tables in this bulletin are a guide to economically justified insulation thicknesses based on calculations listed for specific physical and economic parameters. When large surface areas or high temperatures are involved, however, it is advisable to do an engineering analysis. Programs for this purpose are available through insulation manufacturers and associations. Sources of information are identified on the last page of this bulletin.

## Heat Loss from Uninsulated Surfaces

Identifying the rate of thermal energy (heat) loss from an uninsulated surface is the starting point for understanding the incentive for installing thermal insulation. **Tables 1a, 1b,** and **1c** contain calculated values for the rate of heat loss from horizontal pipes and from either horizontal or vertical flat surfaces. The heat losses are given in millions of BTUs per year for one linear foot of pipe or one square foot of flat surface. These calculations use published correlations for the outside heat transfer coefficient that include the effects of wind and thermal radiation from the exterior surface.

A heat loss computer program published by the American Society for Testing and Materials (ASTM) was used to calculate losses from insulated surfaces [ref. 1]. Uninsulated surface heat losses were calculated using equations published by Incropera and DeWitt [ref. 2]. The heat-loss rates are based on an ambient temperature of 70$^0$F, a wind speed of 10 MPH, an outside surface emittance of 0.80, and a thermal conductivity for carbon steel of 326 Btu∃in/ft$^2$∃hr∃$^0$F at 200$^0$F and 267 Btu∃in/ft$^2$∃hr∃$^0$F at 800$^0$F. The input parameters for **Table 1b** are the same as those for **Table 1a** except that the wind velocity is zero. Thus, **Table 1a** represents outdoor conditions while **Table 1b** represents indoor conditions.

The input parameters used to generate **Table 1c** are the same as those used for **Table 1b** except for the surface emittance of 0.9. Comparison of **Table 1c** and **Table 1b** shows the effect of surface emittance on the heat-loss rate.

Variations in ambient temperature will change the heat-loss rate if the process temperature remains constant. **Figure 1** provides heat-loss multipliers that can be used to calculate heat-loss rates for ambient temperatures below the 70$^0$F standard used for the tables.

**Table 1a. Heat-Loss Rates from Uninsulated Surfaces Exposed to a Ten mph Wind**
**(Millions of BTUs per linear foot per year)**

| Nom. Pipe Diameter | Process Temperature ($^0$F) | | | | | |
|---|---|---|---|---|---|---|
| (inches) | 200 | 400 | 600 | 800 | 1000 | 1200 |
| 1/2 | 2.4 | 6.4 | 11.2 | 17.2 | 25.1 | 35.3 |
| 1 | 3.1 | 8.4 | 15.0 | 23.6 | 35.0 | 50.0 |
| 2 | 4.5 | 12.4 | 22.7 | 36.5 | 55.4 | 81.0 |
| 3 | 6.2 | 16.2 | 30.0 | 49.1 | 75.5 | 111.5 |
| 4 | 7.4 | 20.6 | 36.2 | 59.9 | 92.9 | 138.2 |
| 5 | 8.6 | 24.1 | 44.9 | 71.0 | 111.0 | 165.9 |
| 6 | 9.7 | 27.4 | 51.4 | 85.2 | 128.7 | 193.2 |
| 8 | 11.7 | 33.5 | 63.4 | 105.9 | 166.2 | 243.4 |
| 10 | 13.8 | 39.7 | 75.7 | 127.4 | 201.0 | 302.2 |
| 12 | 15.7 | 45.4 | 87.0 | 147.4 | 233.7 | 352.8 |
| 16 | 18.7 | 54.4 | 105.2 | 179.5 | 286.5 | 434.7 |
| 20 | 22.2 | 65.2 | 127.1 | 218.4 | 350.7 | 534.7 |
| 24 | 25.7 | 76.2 | 149.6 | 256.8 | 414.2 | 633.8 |
| Flat Surfaces | (millions of BTUs per square foot per year) | | | | | |
| Vertical | 2.9 | 9.0 | 19.3 | 36.1 | 61.5 | 98.5 |
| Facing up | 3.0 | 9.8 | 20.8 | 38.2 | 64.2 | 101.9 |
| Facing down | 2.8 | 8.1 | 17.1 | 32.8 | 57.2 | 93.3 |

**Calculated using emittance 0.8 and ambient temperature 70$^0$F**
**One year is 8320 hours of operation**
**Flat surface calculations used characteristic length of 10 feet**

**Table 1b. Heat-Loss Rates from Uninsulated Surfaces with Zero Wind Velocity and 0.8 Exterior Surface Emittance (millions of BTUs per Linear foot per year)**

| Nom. Pipe Diameter | | Process Temperature ($^0$F) | | | | |
|---|---|---|---|---|---|---|
| (inches) | 200 | 400 | 600 | 800 | 1000 | 1200 |
| 1/2 | 0.6 | 2.2 | 4.7 | 8.6 | 14.4 | 22.7 |
| 1 | 0.9 | 3.2 | 7.1 | 13.0 | 21.9 | 34.6 |
| 2 | 1.5 | 5.5 | 12.1 | 22.5 | 38.3 | 60.8 |
| 3 | 2.1 | 7.7 | 17.2 | 32.3 | 55.1 | 87.7 |
| 4 | 2.6 | 9.7 | 21.7 | 41.0 | 70.0 | 111.5 |
| 5 | 3.2 | 11.8 | 26.5 | 50.0 | 85.6 | 136.6 |
| 6 | 3.7 | 13.8 | 31.1 | 59.0 | 101.1 | 161.4 |
| 8 | 4.7 | 17.5 | 39.8 | 75.7 | 130.0 | 207.6 |
| 10 | 5.7 | 21.5 | 48.9 | 93.2 | 160.3 | 256.0 |
| 12 | 6.6 | 25.1 | 57.4 | 109.7 | 188.9 | 302.0 |
| 16 | 8.2 | 31.0 | 71.2 | 136.4 | 235.5 | 377.1 |
| 20 | 10.0 | 38.2 | 87.9 | 169.0 | 292.4 | 469.1 |
| 24 | 11.8 | 53.2 | 118.0 | 201.4 | 349.2 | 560.8 |
| Flat Surfaces | (millions of BTUs per square foot per year) | | | | | |
| Vertical | 2.3 | 8.4 | 18.8 | 35.4 | 60.7 | 97.6 |
| Facing up | 2.6 | 9.5 | 20.7 | 38.0 | 64.0 | 101.6 |
| Facing down | 1.5 | 6.2 | 15.0 | 30.0 | 53.8 | 89.2 |

**Calculated using emittance 0.8 and ambient temperature 70$^0$F**

**Table 1c. Heat-Loss Rates from Uninsulated Surfaces with Zero Wind and 0.9 Exterior Surface Emittance (millions of BTUs per linear foot per year)**

| Nom. Pipe Diameter | Process Temperature ($^0$F) | | | | | |
|---|---|---|---|---|---|---|
| (inches) | 200 | 400 | 600 | 800 | 1000 | 1200 |
| 1/2 | 0.6 | 2.3 | 5.1 | 9.4 | 15.8 | 24.9 |
| 1 | 0.9 | 3.5 | 7.6 | 14.2 | 24.0 | 38.1 |
| 2 | 1.6 | 5.9 | 13.1 | 24.7 | 42.1 | 67.2 |
| 3 | 2.2 | 8.3 | 18.8 | 35.5 | 60.7 | 96.9 |
| 4 | 2.8 | 10.5 | 23.7 | 45.0 | 77.2 | 123.3 |
| 5 | 3.4 | 12.7 | 28.9 | 54.9 | 94.5 | 151.1 |
| 6 | 4.0 | 14.9 | 34.0 | 64.8 | 111.6 | 178.6 |
| 8 | 5.0 | 19.0 | 43.5 | 83.3 | 143.6 | 229.7 |
| 10 | 6.1 | 23.3 | 53.5 | 102.6 | 177.1 | 283.3 |
| 12 | 7.2 | 27.3 | 62.9 | 120.9 | 208.9 | 334.4 |
| 16 | 8.8 | 33.8 | 78.1 | 150.4 | 260.5 | 417.7 |
| 20 | 10.8 | 41.6 | 96.5 | 186.5 | 323.8 | 519.9 |
| 24 | 12.8 | 57.4 | 128.4 | 222.5 | 386.8 | 621.9 |
| Flat Surfaces | (millions of BTUs per square foot per year) | | | | | |
| Vertical | 2.4 | 9.1 | 20.5 | 38.9 | 67.1 | 108.3 |
| Facing up | 2.8 | 10.2 | 22.3 | 41.5 | 70.3 | 112.3 |
| Facing down | 1.7 | 6.9 | 16.7 | 33.5 | 60.1 | 99.9 |

**Calculated using emittance 0.9 and ambient temperature of 70$^0$F**

**(a) Exterior surface emittance 0.1**
**(b) Exterior emittance 0.8**

| Nom. Pipe Diameter (inches) | | Process Temperature ($^0$F) 400 A/B/C | 600 A/B/C | 800 A/B/C | 1000 A/B/C | 1200 A/B/C |
|---|---|---|---|---|---|---|
| 1 | (a) | 152/122/109 | 205/152/131 | 263/186/155 | 327/224/182 | 395/265/212 |
| | (b) | 123/102/95 | 156/120/107 | 193/141/121 | 231/163/136 | 271/187/154 |
| 2 | (a) | 164/128/114 | 224/163/140 | 291/203/168 | 364/246/200 | 440/293/234 |
| | (b) | 130/106/97 | 168/127/112 | 209/150/128 | 253/175/146 | 297/202/165 |
| 4 | (a) | 174/137/120 | 242/179/150 | 316/225/183 | 396/276/220 | 480/330/259 |
| | (b) | 136/111/100 | 178/135/117 | 223/162/136 | 270/192/157 | 318/223/179 |
| 8 | (a) | 160/145/126 | 217/192/159 | 281/245/197 | 350/302/238 | 422/363/283 |
| | (b) | 124/115/103 | 158/142/122 | 196/172/143 | 235/204/166 | 275/238/190 |
| 12 | (a) | 162/148/130 | 222/197/167 | 288/252/209 | 358/312/254 | 432/374/302 |
| | (b) | 125/116/105 | 160/144/125 | 197/175/148 | 237/208/173 | 278/243/200 |
| 16 | (a) | 170/154/134 | 235/207/174 | 306/266/218 | 382/330/266 | 461/397/318 |
| | (b) | 130/119/107 | 167/149/129 | 208/182/153 | 250/218/180 | 294/254/208 |
| 24 | (a) | 174/157/137 | 241/212/178 | 315/274/224 | 393/340/274 | 475/409/328 |
| | (b) | 131/120/108 | 170/152/131 | 211/186/156 | 255/222/184 | 299/260/212 |
| Flat Surfaces | | (millions of BTUs per square foot per year) | | | | |
| Vertical | | | | | | |
| | (a) | 186/162/148 | 263/222/197 | 346/288/252 | 435/359/312 | 528/434/376 |
| | (b) | 146/129/119 | 194/166/149 | 246/206/183 | 299/249/218 | 353/293/256 |
| Facing up | | | | | | |
| (a) | | 173/151/138 | 240/203/181 | 315/261/228 | 395/324/281 | 480/391/337 |
| (b) | | 141/125/116 | 186/159/144 | 235/197/175 | 285/237/208 | 337/278/243 |
| Facing down | | | | | | |
| (a) | | 211/184/167 | 303/258/229 | 402/338/297 | 503/423/370 | 606/510/446 |
| (b) | | 154/135/124 | 207/176/158 | 263/221/195 | 320/267/234 | 376/313/275 |

**Calculated using ambient temperature 80$^0$F and zero wind velocity. First increment of insulation is one inch for flat surfaces and for pipes with nominal diameters of six inches or less; 1.5 inches for larger size diameters.**

## Exterior Surface Temperatures for Burn Protection

Safety considerations associated with systems operating at temperatures above ambient can outweigh energy savings. The computer program used to calculate the numbers in the preceding tables was used to calculate exterior surface temperatures for an ambient temperature of 80$^0$F, a wind speed of zero, and an exterior surface emittance of 0.1. The emittance of 0.1 was considered to be representative of aluminum jacketing. An emittance of 0.8 was considered to be representative of non-metallic surfaces. These are not, however, the most severe conditions for determining surface temperatures for personnel protection evaluations.

**Table 3** contains surface temperatures for one, two, and three increments of thermal insulation. The entries in **Table 3** are degrees in F in a format A/B/C where A is the calculated temperature for one increment of insulation, B is for two increments, and C is for three increments.

Heat-flow and temperature calculations were used to determine the thicknesses of thermal insulation needed to limit the outside surface temperatures for personnel protection to 125$^0$F for highly conductive (metal) surfaces or 150$^0$F for non-conductive surfaces. **Tables 4a** and **4b** present results for exterior emittances of 0.1 (aluminum jacketing) and 0.8 (nonreflective covering) respectively. Since insulation products are generally available in specific thickness increments, the product thickness that meets or exceeds those shown in **Tables 4a** and **4b** should be used. If the ambient temperature is greater than 80$^0$F, the exterior surface temperatures will be greater than the values given in **Table 3.** For example, a 10$^0$F change in the ambient temperature will change the exterior surface temperature by about 9$^0$F for pipes three inches or greater in diameter and about 8$^0$F for pipes less than three inches in diameter. Other factors such as solar loading, wet high-conductivity insulation, or new low-emittance jacketing can increase surface temperatures.

**Table 4a. Insulation Thickness Required to Obtain Surface Temperatures Below 125$^0$F with Zero Wind**

| Nom. Pipe Diameter | Process Temperature ($^0$F) | | | | | |
|---|---|---|---|---|---|---|
| (inches) | 200 | 400 | 600 | 800 | 1000 | 1200 |
| 1/2 | 1 | 2 | 3 | 5 | 7 | 10 |
| 1 | 1 | 2 | 3.5 | 6 | 8 | >10 |
| 2 | 1 | 2.5 | 4.5 | 7 | 9 | >10 |
| 3 | 1 | 2.5 | 5 | 8 | >10 | >10 |
| 4 | 1 | 3 | 5 | 8 | >10 | >10 |
| 5 | 1 | 3 | 6 | 9 | >10 | >10 |
| 6 | 1 | 3 | 6 | 9 | >10 | >10 |
| 8 | 1 | 3.5 | 6 | 10 | >10 | >10 |
| 10 | 1 | 3.5 | 7 | 10 | >10 | >10 |
| 12 | 1 | 3.5 | 7 | 10 | >10 | >10 |
| 16 | 1 | 4 | 8 | >10 | >10 | >10 |
| 20 | 1 | 4 | 8 | >10 | >10 | >10 |
| 24 | 1 | 4 | 8 | >10 | >10 | >10 |
| Flat Surfaces | | | | | | |
| Vertical | 1 | 4 | 8 | >10 | >10 | >10 |
| Facing up | 1 | 3 | 6 | 10 | >10 | >10 |
| Facing down | 1.5 | 6 | >10 | >10 | >10 | >10 |

**Calculated using emittance 0.1 and ambient temperature 80$^0$F**

**Table 4b. Insulation Thickness Required to Obtain Surface Temperatures Below 150$^0$F with Zero Wind**

| Nom. Pipe Diameter (inches) | Process Temperature ($^0$F) 200 | 400 | 600 | 800 | 1000 | 1200 |
|---|---|---|---|---|---|---|
| 1/2 | 1 | 1 | 1.5 | 2 | 2.5 | 3 |
| 1 | 1 | 1 | 1.5 | 2 | 2.5 | 3.5 |
| 2 | 1 | 1 | 1.5 | 2 | 3 | 4 |
| 3 | 1 | 1 | 1.5 | 2.5 | 3.5 | 4.5 |
| 4 | 1 | 1 | 2 | 2.5 | 3.5 | 4.5 |
| 5 | 1 | 1 | 2 | 2.5 | 4 | 4.5 |
| 6 | 1 | 1 | 2 | 3 | 4 | 5 |
| 8 | 1 | 1 | 2 | 3 | 4 | 6 |
| 10 | 1 | 1 | 2 | 3 | 4.5 | 6 |
| 12 | 1 | 1 | 2 | 3 | 4.5 | 6 |
| 16 | 1 | 1 | 2 | 3.5 | 4.5 | 6 |
| 20 | 1 | 1 | 2.5 | 3.5 | 5 | 7 |
| 24 | 1 | 1 | 2.5 | 3.5 | 5 | 7 |
| Flat Surfaces | | | | | | |
| Vertical | 1 | 1 | 2 | 3.5 | 5 | 7 |
| Facing up | 1 | 1 | 2 | 3 | 4.5 | 7 |
| Facing down | 1 | 1.5 | 2.5 | 4 | 6 | 9 |

**Calculated using emittance 0.8 and ambient temperature 80$^0$F**

**Table 5a. Economic Thickness of Insulation (inches) with Surface Exposed to 10 mph Wind**

| Nom. Pipe Diameter (inches) | Process Temperature ($^0$F) 200 | 400 | 600 | 800 | 1000 | 1200 |
|---|---|---|---|---|---|---|
| 1/2 | 1 | 1 | 1.5 | 2.5 | 2.5 | 3 |
| 1 | 1 | 1.5 | 2 | 2.5 | 3 | 3 |
| 2 | 1 | 1.5 | 2.5 | 3 | 3 | 4 |
| 3 | 1 | 2 | 2.5 | 3 | 4 | 4 |
| 4 | 1 | 2 | 3 | 3 | 4 | 4 |
| 5 | 1 | 2 | 3 | 4 | 4 | 4 |
| 6 | 1.5 | 2 | 3 | 4 | 4 | 4 |
| 8 | 1.5 | 2.5 | 3 | 4 | 4 | 4 |
| 10 | 1.5 | 2.5 | 4 | 4 | 4 | 4 |
| 12 | 1.5 | 2.5 | 4 | 4 | 4 | 4 |
| 16 | 1.5 | 2.5 | 4 | 4 | 4 | 6 |
| 20 | 1.5 | 2.5 | 4 | 4 | 4 | 6 |
| 24 | 1.5 | 2.5 | 4 | 4 | 4 | 6 |
| Flat Surfaces | | | | | | |
| Vertical | 2 | 3 | 4 | 4 | 6 | 6 |
| Facing up | 2 | 3 | 4 | 4 | 6 | 6 |
| Facing down | 1.5 | 3 | 4 | 4 | 6 | 6 |

**Calculated using emittance 0.1 and ambient temperature 70$^0$F and $3 per million BTUs**

## Economic Insulation Thickness

A thermal insulation thickness that satisfies an economic assessment of the minimal cost of owning and operating a thermal system is commonly called the Aeconomic thickness.≅ Economic thicknesses are determined from the value of energy that is saved, the cost and performance of insulation, and a number of financial factors. A detailed analysis is justified for systems that operate at elevated temperatures or if large surface areas are involved.

Sources of available information for detailed analyses are listed on the back page of this bulletin. A set of calculated economic thicknesses are presented in **Tables 5a, 5b,** and **5c**. **Tables 5a-c** contain nominal insulation thicknesses for environmental conditions of $70^0$F with a wind speed of 10 mph. Since a large fraction of industrial insulation is jacketed, the exterior surface emittance was assigned a value of 0.1. The economic strategy chosen for the calculation was minimization of annual cost for an anticipated life of seven years. Calculations for economic thickness were limited to thickness of ten inches or less.

Given the importance of cost of energy as a factor, three levels of energy cost were considered: $3 per million BTUs, $6 per million BTUs, and $10 per million BTUs. These costs are for energy delivered to the system being considered and should include energy conversion efficiency and other losses. The entries in **Tables 5a, 5b,** and **5c** give the calculated economic thicknesses for the three energy costs cited above. The factors used in the economic thickness calculations are shown below.

**Table 5b. Economic Thickness of Insulation (Inches) with Surface Exposed to 10 mph Wind**

| Nom. Pipe Diameter | Process Temperature ($^0$F) | | | | | |
|---|---|---|---|---|---|---|
| (inches) | 200 | 400 | 600 | 800 | 1000 | 1200 |
| 1/2 | 1 | 1.5 | 2.5 | 3 | 3 | 3 |
| 1 | 1 | 2 | 3 | 3 | 4 | 4 |
| 2 | 1.5 | 2.5 | 3 | 4 | 4 | 4 |
| 3 | 1.5 | 2.5 | 4 | 4 | 4 | 4 |
| 4 | 1.5 | 3 | 4 | 4 | 4 | 6 |
| 5 | 1.5 | 3 | 4 | 4 | 4 | 6 |
| 6 | 1.5 | 3 | 4 | 4 | 6 | 6 |
| 8 | 1.5 | 3 | 4 | 4 | 6 | 6 |
| 10 | 1.5 | 4 | 4 | 4 | 6 | 6 |
| 12 | 2 | 4 | 4 | 4 | 6 | 6 |
| 16 | 2 | 4 | 4 | 6 | 6 | 8 |
| 20 | 2 | 4 | 4 | 6 | 6 | 8 |
| 24 | 2 | 4 | 4 | 6 | 6 | 8 |
| Flat Surfaces | | | | | | |
| Vertical | 2.5 | 4 | 4 | 6 | 10 | 10 |
| Facing up | 2.5 | 4 | 4 | 6 | 10 | 10 |
| Facing down | 2.5 | 4 | 4 | 6 | 10 | 10 |

**Calculated using emittance 0.1 and ambient temperature of $70^0$F and $6 per million BTUs**

**Table 5c. Economic Thickness of Insulation (Inches) with Surface Exposed to 10 mph Wind**

| Nom. Pipe Diameter (inches) | Process Temperature ($^0$F) 200 | 400 | 600 | 800 | 1000 | 1200 |
|---|---|---|---|---|---|---|
| 1/2 | 1 | 2.5 | 3 | 3 | 4 | 4 |
| 1 | 1.5 | 2.5 | 3 | 4 | 4 | 4 |
| 2 | 1.5 | 3 | 4 | 4 | 4 | 6 |
| 3 | 2 | 3 | 4 | 4 | 6 | 6 |
| 4 | 2 | 3 | 4 | 4 | 6 | 6 |
| 5 | 2 | 4 | 4 | 6 | 6 | 8 |
| 6 | 2 | 4 | 4 | 6 | 6 | 8 |
| 8 | 2.5 | 4 | 4 | 6 | 6 | 10 |
| 10 | 2.5 | 4 | 4 | 6 | 9 | 9 |
| 12 | 2.5 | 4 | 4 | 6 | 9 | 10 |
| 16 | 2.5 | 4 | 6 | 6 | 9 | 10 |
| 20 | 2.5 | 4 | 6 | 6 | 9 | 10 |
| 24 | 3 | 4 | 6 | 6 | 10 | 10 |
| Flat Surfaces | | | | | | |
| Vertical | 3 | 4 | 6 | 10 | 10 | 10 |
| Facing up | 4 | 4 | 6 | 10 | 10 | 10 |
| Facing down | 3 | 4 | 6 | 10 | 10 | 10 |

**Calculated using emittance 0.1 and ambient temperature 70$^0$F and $10 per million BTUs**

Annual Fuel Inflation Rate........................................................ 6%
Annual Hours of Operation.................................................... 8320
Plant Depreciation Period (years).................................................. 7
New Insulation Depreciation (years) ............................................. 7
Incremental Equip. Invest. Rate ($/MMBTU/hr) .......................... 3.47
Annual Insulation Maintenance (% of new cost)............................. 2
Plant Maintenance (%) ................................................................. 1
Interest Rate (%) ............................................................ 10
Income Tax Rate (%)...................................................... 30
Labor Cost ($/hr)...................................................... 38.35
Labor Productivity from FEA [3] report
Base price of Insulation -
($/ft for two inches of jacketed insulation
for a nominal 2-inch diameter pipe)........................... 4.86
($/ft for two inches of flat insulation)........................ 2.31
Material Price adjustment factors from FEA [3] report

**Table 6** contains the energy savings that result from the application of the Aeconomic thickness≅ insulation. The contents of this table are based on an exterior surface emittance of 0.1, a 10 mph wind, and a 70$^0$F ambient temperature.

The value of saved energy was used to calculate simple payback times for the three levels of energy cost. The simple paybacks in months are listed in **Tables 7a-c**.

**Table 6. Savings in Heat-loss Rate with Economic Insulation Thickness with Surface Exposed to 10 mph Wind (millions of BTUs per linear foot per year)**

| Nom. Pipe Diameter (inches) | Process Temperature ($^0$F) 200 | 400 | 600 | 800 | 1000 | 1200 |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| 1/2 | 2.2 | 6.0 | 10.6 | 16.4 | 23.9 | 33.6 |
| 1 | 2.9 | 8.0 | 14.4 | 22.6 | 33.6 | 48.2 |
| 2 | 4.3 | 11.9 | 21.8 | 35.3 | 53.6 | 78.5 |
| 3 | 5.9 | 15.5 | 29.1 | 47.6 | 73.3 | 108.4 |
| 4 | 7.0 | 20.0 | 35.1 | 58.1 | 90.3 | 135.4 |
| 5 | 8.2 | 23.3 | 43.7 | 69.0 | 108.1 | 162.8 |
| 6 | 9.2 | 26.6 | 50.0 | 82.9 | 126.1 | 189.6 |
| 8 | 11.2 | 32.4 | 61.7 | 103.2 | 163.1 | 239.2 |
| 10 | 13.2 | 38.7 | 73.7 | 124.2 | 197.4 | 297.3 |
| 12 | 15.1 | 44.2 | 84.8 | 143.7 | 229.7 | 347.2 |
| 16 | 17.9 | 53.0 | 102.4 | 176.2 | 281.7 | 429.3 |
| 20 | 21.3 | 63.5 | 123.7 | 214.5 | 344.9 | 528.3 |
| 24 | 24.6 | 74.2 | 145.7 | 252.2 | 407.5 | 626.5 |
| Flat Surfaces | (millions of BTUs per square foot per year) | | | | | |
| Vertical | 2.8 | 8.8 | 18.8 | 35.5 | 60.9 | 97.8 |
| Facing up | 2.9 | 9.5 | 20.3 | 37.6 | 63.7 | 101.2 |
| Facing down | 2.6 | 7.8 | 16.6 | 32.2 | 56.7 | 92.6 |

**Calculated using emittance 0.1 and ambient temperature of $70^0$F and $6 per million BTUs**

**Table 7a. Simple Payback (Months) at Economic Thickness with Surface Exposed to 10 mph Wind**

| Nom. Pipe Diameter | Process Temperature ($^0$F) | | | | | |
|---|---|---|---|---|---|---|
| (inches) | 200 | 400 | 600 | 800 | 1000 | 1200 |
| 1/2 | 12.0 | 4.5 | 3.1 | 2.7 | 1.8 | 1.5 |
| 1 | 9.6 | 4.2 | 2.9 | 2.1 | 1.6 | 1.1 |
| 2 | 7.5 | 3.2 | 2.4 | 1.7 | 1.1 | 1.0 |
| 3 | 6.2 | 3.4 | 2.1 | 1.4 | 1.2 | 0.8 |
| 4 | 5.8 | 2.9 | 2.2 | 1.3 | 1.1 | 0.7 |
| 5 | 5.5 | 2.7 | 1.9 | 1.6 | 1.0 | 0.7 |
| 6 | 6.1 | 2.6 | 1.9 | 1.4 | 0.9 | 0.6 |
| 8 | 5.8 | 2.8 | 1.7 | 1.2 | 0.8 | 0.5 |
| 10 | 5.6 | 2.7 | 2.0 | 1.2 | 0.7 | 0.5 |
| 12 | 5.5 | 2.6 | 1.9 | 1.1 | 0.7 | 0.5 |
| 16 | 5.9 | 2.6 | 1.9 | 1.1 | 0.7 | 0.8 |
| 20 | 6.1 | 2.7 | 1.8 | 1.1 | 0.7 | 0.7 |
| 24 | 6.0 | 2.6 | 1.8 | 1.0 | 0.6 | 0.7 |
| Flat Surfaces | | | | | | |
| Vertical | 12.5 | 4.6 | 2.4 | 1.3 | 1.1 | 0.7 |
| Facing up | 12.1 | 4.3 | 2.2 | 1.2 | 1.1 | 0.7 |
| Facing down | 12.3 | 5.2 | 2.7 | 1.4 | 1.2 | 0.7 |

**Calculated using emittance 0.1 and ambient temperature $70^0$F and $3 per million BTUs**

**Table 7b. Simple Payback (Months) at Economic Thickness with Surface Exposed to 10 mph Wind**

| Nom. Pipe Diameter | Process Temperature ($^0$F) | | | | | |
|---|---|---|---|---|---|---|
| (inches) | 200 | 400 | 600 | 800 | 1000 | 1200 |
| 1/2 | 6.0 | 2.7 | 2.0 | 1.5 | 1.0 | 0.7 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 4.8 | 2.5 | 1.8 | 1.2 | 1.1 | 0.8 |
| 2 | 4.5 | 2.2 | 1.3 | 1.1 | 0.7 | 0.5 |
| 3 | 3.7 | 1.9 | 1.5 | 0.9 | 0.6 | 0.4 |
| 4 | 3.4 | 1.9 | 1.4 | 0.8 | 0.5 | 0.6 |
| 5 | 3.2 | 1.8 | 1.2 | 0.8 | 0.5 | 0.6 |
| 6 | 3.1 | 1.7 | 1.2 | 0.7 | 0.8 | 0.5 |
| 8 | 2.9 | 1.6 | 1.0 | 0.6 | 0.7 | 0.5 |
| 10 | 2.8 | 1.9 | 1.0 | 0.6 | 0.6 | 0.4 |
| 12 | 3.3 | 1.8 | 0.9 | 0.6 | 0.6 | 0.4 |
| 16 | 3.4 | 1.8 | 0.9 | 0.9 | 0.6 | 0.6 |
| 20 | 3.4 | 1.8 | 0.9 | 0.9 | 0.6 | 0.5 |
| 24 | 3.4 | 1.7 | 0.9 | 0.9 | 0.5 | 0.5 |
| Flat Surfaces | | | | | | |
| Vertical | 6.7 | 2.6 | 1.2 | 1.0 | 0.8 | 0.5 |
| Facing up | 6.5 | 2.4 | 1.1 | 0.9 | 0.8 | 0.5 |
| Facing down | 7.1 | 2.9 | 1.4 | 1.1 | 0.9 | 0.5 |

**Calculated using emittance 0.1 and ambient temperature 70$^0$F and $6 per million BTUs**

**Table 7c. Simple Payback (Months) at Economic Thickness with Surface Exposed to 10 mph Wind**

| Nom. Pipe Diameter | Process Temperature ($^0$F) | | | | | |
|---|---|---|---|---|---|---|
| (inches) | 200 | 400 | 600 | 800 | 1000 | 1200 |
| 1/2 | 3.6 | 2.1 | 1.4 | 0.9 | 0.9 | 0.6 |
| 1 | 3.4 | 1.7 | 1.1 | 1.0 | 0.7 | 0.5 |
| 2 | 2.7 | 1.5 | 1.1 | 0.7 | 0.4 | 0.6 |
| 3 | 2.6 | 1.3 | 0.9 | 0.6 | 0.7 | 0.4 |
| 4 | 2.4 | 1.1 | 0.8 | 0.5 | 0.6 | 0.4 |
| 5 | 2.3 | 1.4 | 0.7 | 0.8 | 0.5 | 0.5 |
| 6 | 2.2 | 1.3 | 0.7 | 0.7 | 0.5 | 0.5 |
| 8 | 2.4 | 1.2 | 0.6 | 0.6 | 0.4 | 0.5 |
| 10 | 2.3 | 1.1 | 0.6 | 0.6 | 0.6 | 0.4 |
| 12 | 2.2 | 1.1 | 0.6 | 0.6 | 0.6 | 0.4 |
| 16 | 2.3 | 1.1 | 1.0 | 0.6 | 0.6 | 0.4 |
| 20 | 2.3 | 1.1 | 0.9 | 0.5 | 0.5 | 0.4 |
| 24 | 2.6 | 1.0 | 0.9 | 0.5 | 0.6 | 0.4 |
| Flat Surfaces | | | | | | |
| Vertical | 4.3 | 1.6 | 1.1 | 0.8 | 0.5 | 0.3 |
| Facing up | 4.7 | 1.4 | 1.0 | 0.8 | 0.5 | 0.3 |
| Facing down | 4.5 | 1.8 | 1.2 | 0.9 | 0.5 | 0.3 |

**Calculated using emittance 0.1 and ambient temperature 70$^0$F and $10 per million BTUs**

## INFORMATION SOURCES

**North American Insulation Manufacturers Association**
3E Plus-Insulation Thickness Computer Program
44 Canal Center Plaza - Suite 310
Alexandria, Virginia 22314

**SofTech$^2$**
P.O. Box 55232
Grand Junction, Colorado 81505

**National Commercial & Industrial Insulation Standards**
Midwest Insulation Contractors Association
2017 South 139th Circle
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