INDUSTRIAL INSULATION

for Systems Operating Above Ambient Temperature

Background

This bulletin was prepared to provide readily accessible information about the use of thermal insulation on piping and flat surfaces where their operating temperatures are above the temperature of their surroundings. Installation of thermal insulation can significantly reduce the thermal energy (heat) lost with these surfaces. This reduction is economically sound and aids in energy conservation. In addition, the use of insulation can be shown to be cost effective in facilities where lost heat has value and for systems operating above 200 °F, insulation contributes to worker safety.

When insulation is applied to pipes or flat surfaces, the temperature distribution changes within the system. In general, because the operating temperatures of pipes and walls are increased by the application of insulation, the resulting changes in system temperature must be taken into account, especially in the case of temperature sensitive processes or materials.

The tables contained in this bulletin provide the means for quick estimates of the possible savings with thermal insulation. Economically justified insulation thicknesses have also been calculated and listed in this bulletin 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 provides 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 effect of wind. Thermal radiation from the exterior surface has been included in the calculation.

A computer program for heat loss published by the American Society for Testing and Materials (ASTM) was used to calculate heat losses from insulated surfaces [ref. 1]. Heat Losses from uninsulated surfaces were calculated using equations published by Incropera and DeWitt [ref. 2]. The heat-loss rates are based on an ambient temperature of 70°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-F) at 200°F and 267 (Btu-in)/(ft^2-hr-F) at 800°F. The input parameters for **Table 1b** are the same as those for **Table 1a** except that the wind velocity is zero. Table 1a represents outdoor conditions while **Table 1b** represents indoor conditions.

Table 1a. Heat-Loss Rates from Uninsulated Surfaces Exposed to 10-MPH Wind (millions of Btus per linear foot per year)

Nom. Pipe Diameter (inches)	Process Temperature (°F)					
	200	400	600	800	1000	1200
½	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°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 Exposed to Zero Wind Velocity

(millions of Btus per linear foot per year)

Nom. Pipe Diameter (inches)	Process Temperature (°F)					
	200	400	600	800	1000	1200
½	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°F

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.

Changes 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 70°F.

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

Nom. Pipe Diameter (inches)	Process Temperature (°F)					
	200	400	600	800	1000	1200
½	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 70°F

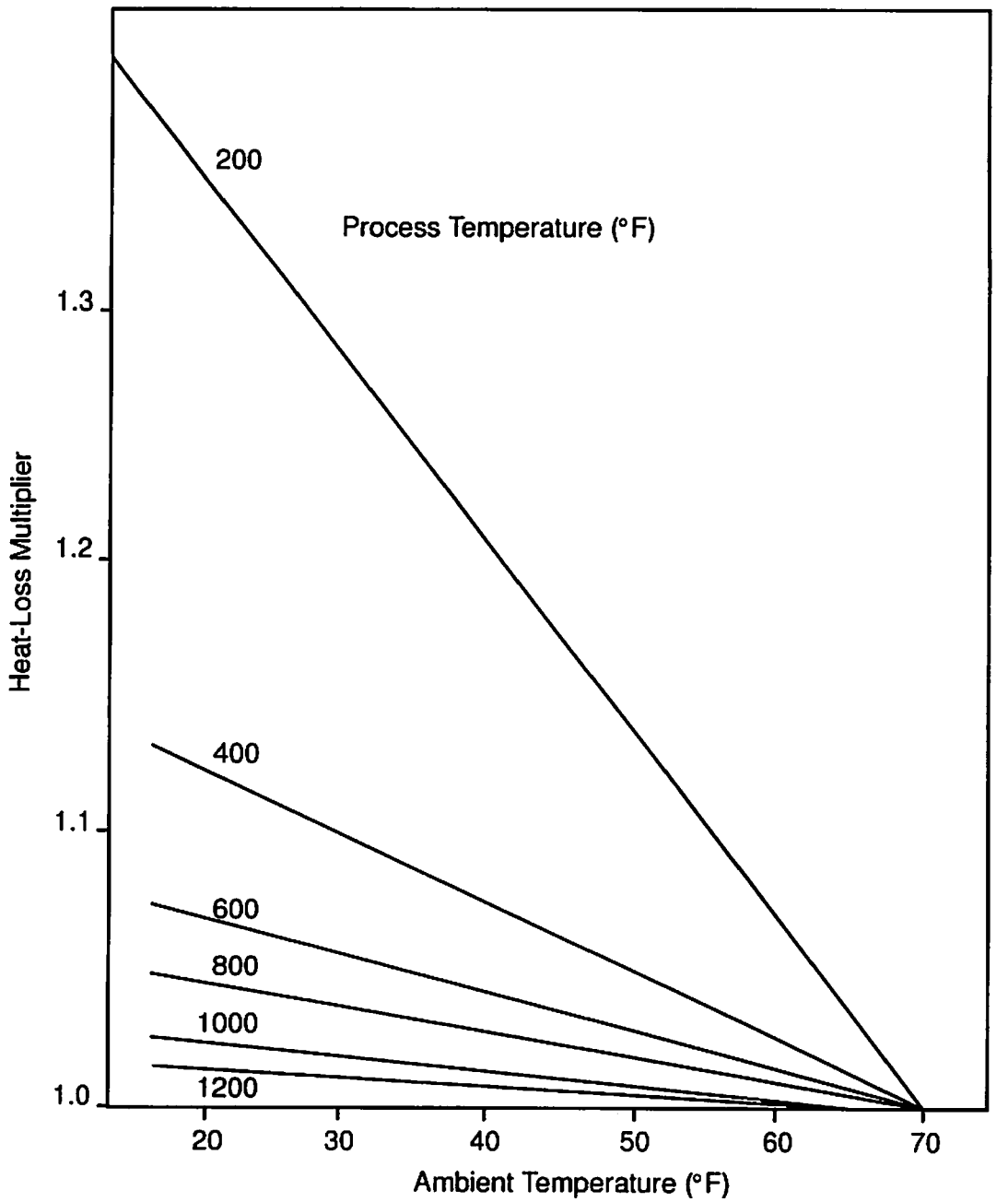

Figure 1. Multipliers for Adjusting Table 1 Heat-loss Rates for Ambient Temperatures between 20 and 70°F

Energy Savings with One Increment of Insulation

Systems operating above ambient temperature should be insulated with a t least one inch (one increment) of insulation. The first increment of insulation is one inch for pipes with nominal diameter of six inches or less and 1.5 inches for larger pipe diameters. Calculated savings for one increment of insulation expressed as a percentage of the uninsulated-surface loss range from 91 to 95% for pipes and 86 to 94% for flat surfaces.

These percent savings vary with nominal pipe diameter and process temperature. The heat-loss percent savings for flat surfaces increase as the process temperatures increase with 86 to 87% savings at 200°F and 93 to 94 % savings at 1200°F.

Economic insulation thicknesses depend on the cost of fuel being used, as demonstrated in the next section. **Table 2** contains potential savings after the first increment of insulation is installed. These heat-loss rates can be used to justify greater thicknesses of pipe or flat-surface insulation.

Table 2. Heat-Loss Rates from Pipes and Surfaces after First Increment of Insulation Exposed to 10-MPH Wind (millions of Btus per linear foot per year)

Nom. Pipe Diameter (inches)	Process Temperature (°F)					
	200	400	600	800	1000	1200
½	0.14	0.47	0.91	1.47	2.15	2.95
1	0.18	0.59	1.14	1.85	2.70	3.70
2	0.27	0.89	1.73	2.80	4.10	5.62
3	0.37	1.21	2.37	3.83	5.61	7.70
4	0.45	1.45	2.83	4.59	6.71	9.21
5	0.55	1.77	3.46	5.60	8.19	11.25
6	0.65	2.11	4.11	6.66	9.75	13.38
8	0.57	1.84	3.59	5.81	8.51	11.67
10	0.67	2.16	4.20	6.80	9.96	13.66
12	0.77	2.50	4.88	7.90	11.56	15.87
16	1.01	3.29	6.41	10.37	15.18	20.84
20	1.24	4.03	7.86	12.73	18.63	25.57
24	1.47	4.78	9.32	15.09	22.09	30.31
Flat Surfaces	(millions of Btus per square foot per year)					
Vertical	0.33	1.06	2.07	3.35	4.90	6.73
Facing up	0.33	1.07	2.09	3.39	4.96	6.81
Facing down	0.32	1.03	2.02	3.27	4.79	6.58

Calculated using emittance 0.8, ambient temperature 70°F, and 10 mph wind

Note: First increment of insulation is one inch for flat surfaces and pipes with nominal diameter of six inches or less; 1-1/2 inch for larger pipe 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°F, a wind speed of zero, and an exterior surface emittance of 0.1. The emittance of 0.1 was taken to be representative of aluminum jacketing. An emittance of 0.8 was taken to be representative of non-metallic surfaces. These conditions are not 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 F in the 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.

Table 3. Calculated Surface Temperatures for Systems with One (or 1.5), Two, or Three Inches of Thermal Insulation (a) Exterior surface emittance 0.1 (b) Exterior emittance 0.8

Nom. Pipe Diameter (inches)		Process Temperature (°F)				
		400	600	800	1000	1200
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 Surface						
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°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.

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°F for highly conductive (metal) surfaces or 150°F for non-conductive surfaces. The results are given in **Tables 4a** and **4b** 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. The exterior surface temperatures will be greater than the values given in **Table 3** if the ambient temperature is greater than 80°F. A 10°F change in the ambient temperature will change the exterior surface temperature by about 9°F for pipes three inches or greater in diameter and about 8°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 Temperature below 125°F with Zero Wind

Nom. Pipe Diameter (inches)	Process Temperature (°F)					
	200	400	600	800	1000	1200
½	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°F

Table 4b. Insulation Thickness Required to Obtain Surface Temperature below 150°F with Zero Wind

Nom. Pipe Diameter (inches)	Process Temperature (°F)					
	200	400	600	800	1000	1200
½	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°F

Economic Insulation Thickness

A thermal insulation thickness that satisfies an economic evaluation for minimum cost of owning and operating is commonly called the economic thickness. Economic thicknesses are determined from the value of energy that is saved, the cost 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 economic thicknesses have been calculated and are presented in **Tables 5a, 5b**, and **5c**.

Tables 5a-c contain nominal insulation thicknesses for environmental conditions of 70°F with a wind speed of 10 mph. The exterior surface emittance was assigned a value of 0.1 since a large fraction of industrial insulation is jacketed. The economic strategy chosen for the calculation was minimization of annual cost for an anticipated life of seven years. The cost of energy is a very important factor, so three levels of energy costs 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 selected levels of energy cost. The factors

used in the economic thickness calculations are shown below. Calculations for economic thickness were limited to thicknesses of ten inches or less.

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

Nom. Pipe Diameter (inches)	Process Temperature (°F)					
	200	400	600	800	1000	1200
½	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°F and $3 per million Btus

Table 5b. Economic Thickness of Insulation (inches) with Surface Exposed to 10 MPH Wind

Nom. Pipe Diameter (inches)	Process Temperature (°F)					
	200	400	600	800	1000	1200
½	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 70°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 (°F)					
	200	400	600	800	1000	1200
½	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°F and $10 per million Btus

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

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 (°F)					
	200	400	600	800	1000	1200
½	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 70°F and $6 per million Btus

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

Table 7a. Simple Payback Time (months) at Economic Thickness with Surface Exposed to 10 MPH Wind

Nom. Pipe Diameter (inches)	Process Temperature (°F)					
	200	400	600	800	1000	1200
½	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°F and $3 per million Btus

Table 7b. Simple Payback Time (months) at Economic Thickness with Surface Exposed to 10 MPH Wind

Nom. Pipe Diameter (inches)	Process Temperature (°F)					
	200	400	600	800	1000	1200
½	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°F and $6 per million Btus

Table 7c. Simple Payback Time (months) at Economic Thickness with Surface Exposed to 10 MPH Wind

Nom. Pipe Diameter (inches)	Process Temperature (°F)					
	200	400	600	800	1000	1200
½	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°F and $10 per million Btus

INFORMATION SOURCES

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Alexandria, Virginia 22314

SofTech[2]
P.O. Box 55232
Grand Junction, Colorado 81505

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1791 Tullie Circle, NE
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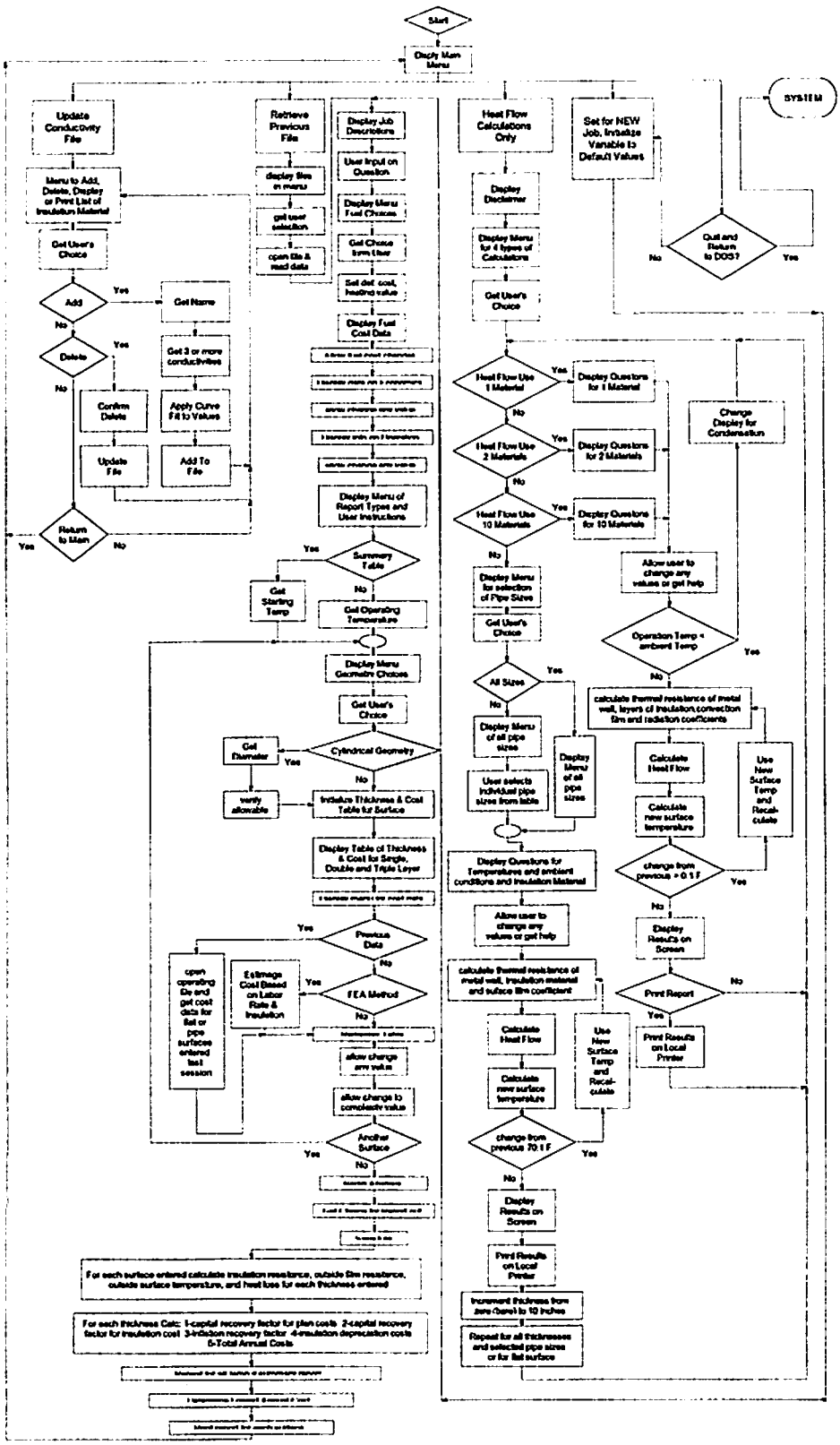
Start
Display Main Menu
SYSTEM
Update Conductivity File
Menu to Add, Delete, Display or Print List of Insulation Material
Get User's Choice
Add
Yes
No
Get Name
Delete
Get 3 or more conductivities
Confirm Delete
Apply Curve Fit to Values
Update File
Add To File
Return to Main
Retrieve Previous File
display files on menu
get user selection
open file & read data
Display Job Descriptions
User Input on Question
Display Menu Fuel Choices
Get Choice from User
Set def. cost, heating value
Display Fuel Cost Data
Display Menu of Report Types and User Instructions
Summary Table
Get Starting Temp
Get Operating Temperature
Display Menu Geometry Choices
Get User's Choice
Cylindrical Geometry
Get Diameter
verify allowable
Initialize Thickness & Cost Table for Surface
Display Table of Thickness & Cost for Single, Double and Triple Layer
Previous Data
open operating file and get cost data for flat or pipe surface entered last session
Estimate Cost Based on Labor Rate & Insulation
FEA Method
allow change any value
allow change to complexity value
Another Surface
For each surface entered calculate insulation resistance, outside film resistance, outside surface temperature, and heat loss for each thickness entered
For each thickness Calc: 1-capital recovery factor for plan costs 2-capital recovery factor for insulation cost 3-inflation recovery factor 4-insulation depreciation costs 5-Total Annual Costs
Heat Flow Calculations Only
Display Disclaimer
Display Menu for 4 types of Calculations
Get User's Choice
Heat Flow Use 1 Material
Display Questions for 1 Material
Heat Flow Use 2 Materials
Display Questions for 2 Materials
Heat Flow Use 10 Materials
Display Questions for 10 Materials
Display Menu for selection of Pipe Sizes
Get User's Choice
All Sizes
Display Menu of all pipe sizes
User selects individual pipe sizes from table
Display Questions for Temperatures and ambient conditions and Insulation Material
Allow user to change any values or get help
calculate thermal resistance of metal wall, insulation material and surface film coefficient
Calculate Heat Flow
Calculate new surface temperature
Use New Surface Temp and Recal-culate
change from previous 70.1 F
Display Results on Screen
Print Results on Local Printer
Increment thickness from zero (bare) to 10 inches
Repeat for all thicknesses and selected pipe sizes or for flat surface
Set for NEW Job, Initialize Variable to Default Values
Quit and Return to DOS?
Change Display for Condensation
Allow user to change any values or get help
Operation Temp < ambient Temp
calculate thermal resistance of metal wall, layers of insulation, convection film and radiation coefficients
Calculate Heat Flow
Calculate new surface temperature
Use New Surface Temp and Recal-culate
change from previous > 0.1 F
Display Results on Screen
Print Report
Print Results on Local Printer