

$(1200 - 610) = 590$ F. Since a temperature of 570 F between the two materials was assumed, it is obvious that a temperature closer to 590, or for instance 586 F may be selected. The mean temperatures of the two insulations corresponding to the new assumptions are $(1200 + 586) \div 2 = 893$ and $(586 + 138) \div 2 = 362$ and the interpolated conductivities corresponding to the new mean temperatures are 0.87 and 0.505 for the diatomaceous silica and 85 per cent magnesia respectively. By substituting in Equation 2:

$$q_0 = \frac{1200 - 138}{\frac{5.36}{0.87} + \frac{2.29}{0.505}} = \frac{1062}{6.16 + 4.53} = 99.3 \text{ Btu}$$

Again referring to Fig. 4, it is seen that the temperature drop from the outer surface of the insulation to the surrounding air for a heat loss of 99.3 Btu = 38 F which corresponds to the surface temperature of 138 F last assumed. The temperature drop through the diatomaceous silica is $99.3 \times 6.16 = 612$ F, corresponding to a temperature of 588 F between the two materials which checks very closely with the temperature of 585 F last assumed. The heat loss is therefore $99.3 \times 8.312 \div 3.312 = 249$ Btu per square foot of pipe surface. Since the surface area per linear foot of 6-in. pipe is 1.734 sq ft (Table 5), the heat loss per linear foot of pipe will be $249 \times 1.734 = 432$ Btu per hour.

The rate of heat loss from a surface maintained at constant temperature is greatly increased by air circulation over the surface. In the case of well-insulated surfaces, the increases in losses due to air velocity are very small as compared with increases from bare surfaces, because of the fact that air flowing over the surface of the insulation can increase only the conductance of heat from surface to air, and cannot change the internal conductance of the insulation itself. The maximum increase in heat loss due to air velocity ranges from about 15 per cent in the case of 1-in. thick insulation, to about 5 per cent in the case of 3-in. thick insulation, provided that the insulation is thoroughly sealed so that air can flow only over the surface. If the conditions are such that the air may circulate through cracks and crevices in the insulation, the increases may be far greater than those given. Therefore, it is essential that insulation be applied in such a manner that air circulation within it or between it and the pipe is avoided.

Fig. 4 shows the loss of heat from canvas-covered, cylindrical surfaces of various outside diameters when the surface to air temperature difference is low. The data are from tests made at Mellon Institute.

The frequent practice of omitting insulation on that portion of a pipe which passes through a masonry wall or which may be in contact with other metals should be avoided. Physical contact between the pipe surface and other structural materials of high thermal conductivity will result in heat transfer much greater than that shown in Tables 1 and 2 for transfer from bare pipe to air.

The saving due to use of insulation on piping is illustrated in *Example 4*.

Example 4. If the steam line given in *Examples 1 and 2* is covered with 1 in. thick 85 per cent magnesia, determine the resulting total annual loss through the insulation. Also compute the monetary value of the annual saving and the percentage of saving over the heat loss from the bare pipe.

Solution. By referring to Fig. 1, the coefficient for 1 in. magnesia on a 2-in. pipe is found to be 0.300 Btu per (hour) (linear foot of pipe) (degree temperature difference) at a temperature difference of 169.4 F. The total hourly loss per linear foot of pipe will then be $0.300 \times 169.4 = 50.8$ Btu. The total annual loss through the insulation = 50.8×165 (linear feet) $\times 4000$ (hours) = 33,500 Mb. The annual bare pipe loss as determined in the solution of *Example 1* was found to be 181,600 Mb. The saving due to insulation is then $181,600 - 33,500 = 148,100$ Mb per year.

From the solution of *Example 2*, it was found that the heat supplied to the system cost \$0.804 per thousand Mb. Therefore, the monetary value of the saving = 0.804 (dollars) $\times 148.1$ (thousand Mb) = \$119.07, or 81.5 per cent of the cost when using uninsulated pipe.

LOW TEMPERATURE PIPE INSULATION

Surfaces maintained at temperatures lower than the surrounding air are insulated to reduce the flow of heat and to prevent condensation. The insulating material should absorb a minimum amount of moisture, because the absorption of moisture substantially increases the conductivity of the material. This property is particularly important in the

TABLE 8. HEAT GAINS FOR INSULATED COLD PIPES

Rates of heat transmission given in Btu per (hour) (Fahrenheit degree temperature difference between fluid in pipe and surrounding still air)

Based on materials having conductivity, $k = 0.30$

NOMINAL PIPE SIZE (INCHES)	ICE WATER THICKNESS			BRINE THICKNESS			HEAVY BRINE THICKNESS		
	Thickness of Insulation (Inches)	Btu Per Linear Foot	Btu Per Sq Ft Pipe Surface	Thickness of Insulation (Inches)	Btu Per Linear Foot	Btu Per Sq Ft Pipe Surface	Thickness of Insulation (Inches)	Btu Per Linear Foot	Btu Per Sq Ft Pipe Surface
$\frac{1}{8}$	1.5	0.110	0.502	2.0	0.098	0.446	2.8	0.087	0.394
$\frac{1}{4}$	1.6	0.119	0.431	2.0	0.111	0.405	2.9	0.094	0.340
1	1.6	0.139	0.403	2.0	0.124	0.352	3.0	0.104	0.294
$1\frac{1}{4}$	1.6	0.155	0.357	2.4	0.131	0.300	3.1	0.113	0.260
$1\frac{1}{2}$	1.5	0.174	0.351	2.5	0.134	0.270	3.2	0.118	0.238
2	1.5	0.200	0.322	2.5	0.151	0.244	3.3	0.134	0.214
$2\frac{1}{4}$	1.5	0.228	0.303	2.6	0.170	0.226	3.3	0.147	0.197
3	1.5	0.269	0.293	2.7	0.186	0.202	3.4	0.162	0.176
$3\frac{1}{4}$	1.5	0.295	0.282	2.9	0.191	0.183	3.5	0.176	0.167
4	1.7	0.294	0.248	2.9	0.209	0.176	3.7	0.182	0.154
5	1.7	0.349	0.239	3.0	0.241	0.165	3.9	0.202	0.138
6	1.7	0.404	0.233	3.0	0.259	0.150	4.0	0.228	0.130
8	1.9	0.455	0.201	3.0	0.318	0.140	4.0	0.263	0.116
10	1.9	0.559	0.198	3.0	0.383	0.135	4.0	0.309	0.110
12	1.9	0.648	0.194	3.0	0.438	0.131	4.0	0.364	0.108

insulation of surfaces that are below the dew-point of the surrounding air. In such cases, due to vapor pressure difference, it is necessary to seal the surface of the insulating material against the penetration of water vapor which would condense within the material, causing a serious increase in heat flow, possible breakdown of the material, and corrosion of metal surfaces. An insulating material with a high degree of moisture absorption might pick up moisture before application and then, when the seal is in place and the temperature of the insulated surface reduced, release that moisture to the cold surface. There are a number of methods of producing vapor seals, some of which have been worked out by insulation manufacturers to suit their products and others by applicators and users. Unless time proven methods are known, specifications of insulation manufacturers should be obtained and followed carefully.

The thickness of insulation required to prevent condensation on the outer surface is that thickness which will raise the temperature of the outer surface of the insulation to a point slightly higher than the dew-point of the surrounding vapor. The dew-point for various humidities can be readily ascertained from a psychrometric chart.

The approximate required thickness of insulation to prevent condensation on pipes and flat metallic surfaces may be obtained from Fig. 5 in which a surface resistance of 0.606 corresponding to a film conductance of