

where

r_2 = outer radius of second layer of insulation, inches.

r_n = outer radius of last layer of insulation, inches.

The method of solving Equation 2, which is the most difficult of the two, is given in Example 3.

Example 3. Compute the heat loss per linear foot of pipe surface per hour from a 6-in. pipe, insulated with a 3-in. thickness of diatomaceous silica, and a 2-in. thickness of 85 per cent magnesia. The pipe is operating at a temperature of 1200 F and is exposed to a room temperature of 80 F.

Solution. In figuring the heat loss from Equation 2, it is necessary to first make an assumption for the outer surface temperature t_s and the temperature between the diatomaceous silica and 85 per cent magnesia insulation, so that the mean temperature of each material can be obtained and the thermal conductivity corresponding to the mean temperature of each material substituted in the formula. First assume an outer surface temperature of 140 F and a temperature of 570 F between the two materials corresponding to a mean temperature of $(1200 + 570) \div 2$ or 885 F for the diatomaceous silica and $(570 + 140) \div 2$ or 355 F for the 85 per cent magnesia insulation. The

TABLE 7. PIPE COVERING FACTORS

TYPES OF INSULATING MATERIALS	TEMPERATURE DIFFERENCE, PIPE TO AIR, F DEG				
	100	200	300	400	500
Corrugated Asbestos—Type					
4 Ply per 1 in.	1.30	1.36	1.42	—	—
6 Ply per 1 in.	1.19	1.23	1.27	—	—
8 Ply per 1 in.	1.15	1.19	1.23	—	—
Laminated Asbestos—Type	0.96	0.98	1.00	1.02	1.04
Mineral Wool—Type	0.98	1.00	1.02	1.05	1.07
Diatomaceous Silica—Type	1.37	1.36	1.35	1.35	1.34
Brown Asbestos Fiber—Type	0.86	0.88	0.91	0.93	0.96

conductivities of these two materials at mean temperatures of 885 and 355 F interpolated from Table 8 are 0.865 and 0.5 Btu respectively.

These values are substituted in Equation 2 and a trial calculation made. For a nominal 6-in. steel pipe $r_1 = 3.312$, $r_2 = 6.312$ and $r_3 = 8.312$ then,

$$q_0 = \frac{1200 - 140}{8.312 \log_e \frac{6.312}{3.312} + \frac{8.312 \log_e \frac{8.312}{6.312}}{0.865} + \frac{1060}{0.5}} = 6.2 + 4.58 = 98.3 \text{ Btu.}$$

The temperature drop from the outer surface of the insulation to the surrounding air for a heat loss of 98.3 Btu is found from Fig. 4 to be 57 F for a 16-in. O.D. cylindrical surface, or $57 + 80$ F room temperature = 137 F surface temperature. Since a surface temperature of 140 F was assumed, it is evident that a temperature closer to 137 F, or, for instance, 138 F should be used for recalculation:

$$q_0 = \frac{1200 - 138}{6.2 + 4.58} = 98.4 \text{ Btu.}$$

Since the temperature drop through each material is equal to the heat flow times the actual resistance of each material the temperature drop through the diatomaceous silica is $98.4 \times 6.2 = 610$ F or the temperature between the two insulating materials is $(1200 - 610) = 590$ 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

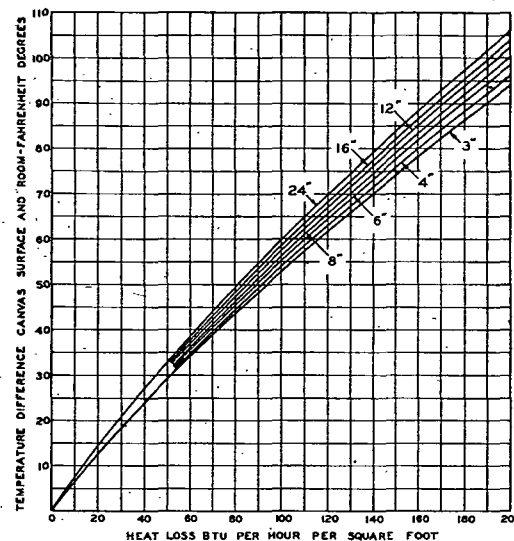


FIG. 4. HEAT LOSS FROM CANVAS-COVERED CYLINDRICAL SURFACES OF VARIOUS DIAMETERS

585 F last assumed. The heat loss is therefore $99.3 \times 8.312 \div 3.312$ or 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