Table 4 .... External Surface per Linear Foot of Copper Tubing

Outside diameter ⅛ in. greater than nominal size

Tube Size (Inches)	Surface Area (Sq Ft)	Tube Size (Inches)	Surface Area (Sq Ft)	Tube Size (Inches)	Surface Area (Sq Ft)
½	0.164	2	0.556	5	1.342
¾	0.229	2½	0.687	6	1.604
1	0.295	3	0.818	8	2.128
1¼	0.360	3½	0.949	...	.....
1½	0.426	4	1.080	...	.....

$$q_e = \frac{t_1 - t_2}{\dfrac{r_e \log_e \dfrac{r_2}{r_1}}{k_1} + \dfrac{r_e \log_e \dfrac{r_3}{r_2}}{k_2} + \cdots} \tag{2}$$

where

r_3 = outer radius of second layer of insulation, inches.
r_e = 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 1500 F diatomaceous earth, and a nominal 2-in. thickness of 85 percent 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 earth and 85 percent 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 equation. First assume an outer surface temperature of 135 F and a temperature of 570 F between the two materials corresponding to a mean temperature of (1200 + 570) ÷ 2 or 885 F for the diatomaceous earth and (570 + 135) ÷ 2 or 352.5 F for the 85 percent magnesia insulation. The conductivities of these two materials at mean temperatures of 885 and 352.5 F, interpolated from Table 1, are 0.677 and 0.466 Btu, respectively.

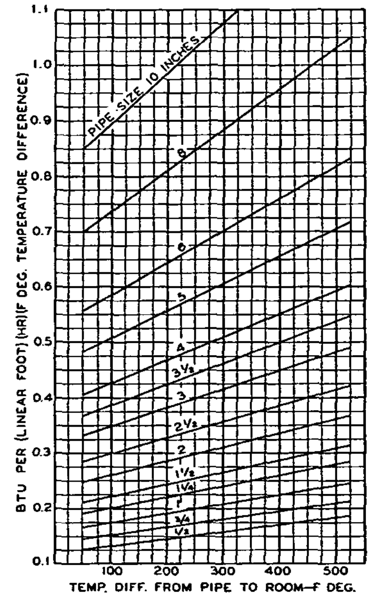

Fig. 1 .... Heat Loss through 1 In. Thick Pipe Insulation

(Use with Table 6 for Various Insulations)

Table 5 .... Area of Flanged Fittings, Square Feet*

Nominal Pipe Size (Inches)	Flanged Coupling		90 Deg Ell		Long Radius Ell		Tee		Cross	
	Standard	Extra Heavy	Standard	Extra Heavy	Standard	Extra Heavy	Standard	Extra Heavy	Standard	Extra Heavy
1	0.320	0.438	0.795	1.015	0.892	1.083	1.235	1.575	1.622	2.07
1¼	0.383	0.510	0.957	1.098	1.084	1.340	1.481	1.925	1.943	2.53
1½	0.477	0.727	1.174	1.332	1.337	1.874	1.815	2.68	2.38	3.54
2	0.672	0.848	1.65	2.01	1.84	2.16	2.54	3.09	3.32	4.06
2½	0.841	1.107	2.09	2.57	2.32	2.76	3.21	4.05	4.19	5.17
3	0.945	1.484	2.38	3.49	2.68	3.74	3.66	5.33	4.77	6.95
3½	1.122	1.644	2.98	3.96	3.28	4.28	4.48	6.04	5.83	7.89
4	1.344	1.914	3.53	4.64	3.96	4.99	5.41	7.07	7.03	9.24
4½	1.474	2.04	3.95	5.02	4.43	5.46	6.07	7.72	7.87	10.07
5	1.622	2.18	4.44	5.47	5.00	6.02	6.81	8.52	8.82	10.97
6	1.82	2.78	5.13	6.99	5.99	7.76	7.84	10.64	10.08	13.75
8	2.41	3.77	6.98	9.76	8.56	11.09	10.55	14.74	13.44	18.97
10	3.43	5.20	10.18	13.58	12.35	15.60	15.41	20.41	19.58	26.26
12	4.41	6.71	13.08	17.73	16.35	18.76	19.67	26.65	24.87	34.11

* Including areas of accompanying flanges bolted to the fitting.

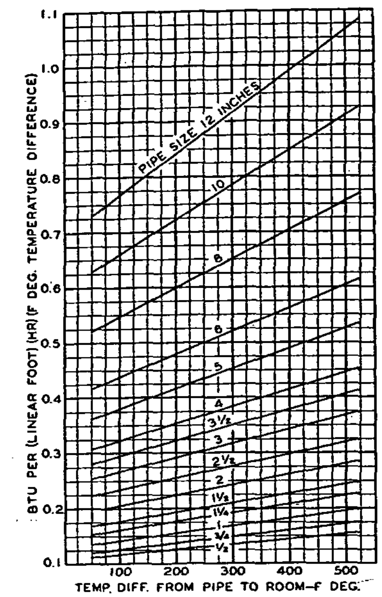

Fig. 2 .... Heat Loss through 1½ In. Thick Pipe Insulation

(Use with Table 6 for Various Insulations)

These values are substituted in Equation 2 and a trial calculation made.

The actual thickness of diatomaceous earth covering is 3.095 in. and that of the 85 percent magnesia is 2.125 in. For a nominal 6-in. steel pipe: $r_1 = 3.312$, $r_2 = 6.407$, and $r_3 = 8.532$. Then,

$$q_e = \frac{1200 - 135}{\dfrac{8.532 \log_e \dfrac{6.407}{3.312}}{0.676} + \dfrac{8.532 \log_e \dfrac{8.532}{6.407}}{0.466}} = \frac{1065}{8.33 + 5.24} = 78.5 \text{ Btu.}$$

The temperature drop from *the outer surface of the insulation* to the surrounding air for a heat loss of 78.5 Btu is found from Fig. 5 to be 49.5 deg for a 17-in. OD cylindrical surface, or 49.5 + 80 F room temperature = 129.5 F surface temperature. Since a surface temperature of 135 F was assumed, it is evident that a temperature closer to 129.5 F, or, for instance, 129 F should be used for recalculation:

$$q_e = \frac{1200 - 129}{8.33 + 5.24} = 78.9 \text{ Btu.}$$

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 earth is 78.9 × 8.33 = 657 F, or the temperature between the two insulating materials is (1200 − 657) = 543 F. Since a temperature *of 570 F* between the two materials was assumed, it is obvious that a temperature closer to 543, or for instance 545 F may be selected.

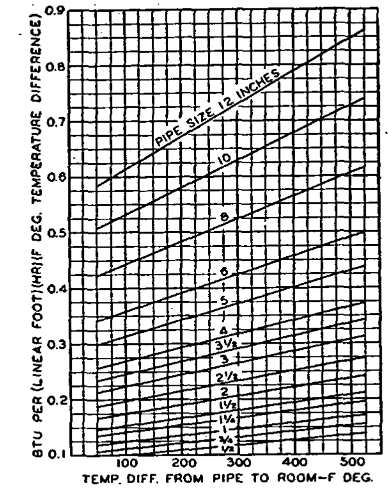

Fig. 3 .... Heat Loss through 2 In. Thick Pipe Insulation

(Use with Table 6 for Various Insulations)

The mean temperatures of the two insulations corresponding to the new assumptions are (1200 + 545) ÷ 2 = 872.5, and (545 + 129) ÷ 2 = 337, and the interpolated *conductivities corresponding* to the new mean temperatures are 0.675 and 0.461 for the diatomaceous earth and 85 percent magnesia, respectively. By substituting in Equation 2

$$q_e = \frac{1200 - 129}{\dfrac{5.63}{0.675} + \dfrac{2.44}{0.461}} = \frac{1071}{8.34 + 5.30} = 78.5 \text{ Btu.}$$

Again referring to Fig. 5, it is seen that the temperature drop from the outer surface of the insulation to the surrounding air

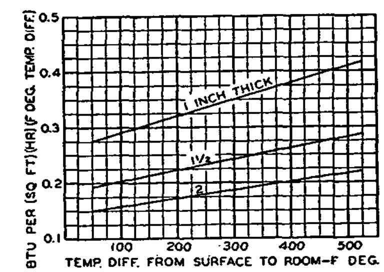

Fig. 4 .... Heat Loss through Insulation on Flat Vertical Surface

(Use with Table 6 for Various Insulations)