$l$ = length of conduit, feet
$t_1$ = temperature of air entering duct, Fahrenheit degrees.
$t_2$ = temperature of air leaving duct, Fahrenheit degrees.
$t_3$ = temperature of air surrounding duct, Fahrenheit degrees.

The heat given up by the air in the duct is:

$$Q_w = 0.24W(t_1 - t_2) = 14.4AV_m\rho_v(t_1 - t_2) \qquad (23)$$

*where*

$W$ = weight of air through duct, pounds per hour
$A$ = cross-sectional area of duct, square feet
$V_m$ = velocity of fluid, feet per minute
$\rho_v$ = density of air at specified temperature at which velocity $V_m$, is measured, pounds per cubic foot.

Equating (22) and (23):

$$\frac{t_1 + t_2 - 2t_3}{t_1 - t_2} = \frac{28.8AV_m\rho_v}{UPl}$$

Let $y = \frac{28.8AV_m\rho_v}{UPl}$ for rectangular ducts, and $\frac{7.2DV_m\rho_v}{Ul}$ for round ducts, and solve for $t_1$ and $t_2$ :

$$t_1 = \frac{t_2(y + 1) - 2t_3}{(y - 1)} \qquad (24) \qquad t_2 = \frac{t_1(y - 1) + 2t_3}{(y + 1)} \qquad (25)$$

For low velocities and long ducts of small cross-section, a somewhat more accurate formula may be used as follows:

$$t_2 = \frac{t_1 - t_3}{e^{\left(\frac{UPl}{14.4A\rho_v V_m}\right)}} + t_3 \qquad (26)$$

*where*

$e$ = Naperian base of logarithms = 2.718.

In using Equations 24, 25, and 26, one of the duct air temperatures will be unknown and will be obtained by substitution of the other known or assumed values.

Heat loss coefficients for insulated ducts with various conductivities are given in Fig. 11. The conductivities of various materials, which are based on mean temperatures, ranging from about 70 to 90 F, will be found in Table 2 of Chapter 6. For cases where the mean temperature is other than that at which the test was conducted, a correction should be made. However, in most cases the effect of this factor will be small and may be neglected.

*Example 5.* Determine the entering air temperature and heat loss for a duct 24 × 36 in. cross-section and 70 ft in length, insulated with ½ in. of a material having a conductivity of 0.35 Btu at 86 F mean temperature, carrying air at a velocity of 1200 fpm, measured at 70 F, to deliver air at 120 F with air surrounding the duct at 40 F.

*Solution.* Referring to Fig. 11, the over-all heat transmission coefficient is found to be 0.49 Btu. From Table 1, Chapter 3 the density of air at 70 F and 29.921 in. Hg



is found to be 1/13.348 = 0.0749 lb per cubic foot. Substituting these and the other given values in Equation 24:

$$y = \frac{28.8 \times 6 \times 1200 \times 0.0749}{0.49 \times 10 \times 70} = 45.3$$

$$t_1 = \frac{120(45.3 + 1) - 80}{45.3 - 1} = 123.7$$

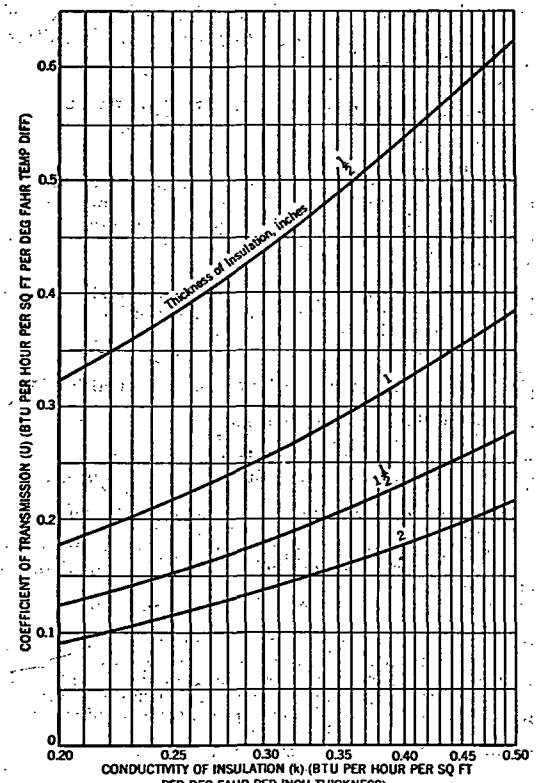



FIG. 11. HEAT LOSS COEFFICIENTS FOR INSULATED DUCTS[a]

[a] For round ducts less than 30 in. diameter, increase heat transmission values by the percentages shown.

| THICKNESS OF INSULATION (Inches) | ½ | 1 | 1½ | 2 |
|---|---|---|---|---|
| 21 to 30 in. Duct Diameter | 1% | 2% | 3% | 4% |
| 12 to 21 in. Duct Diameter | 3% | 5% | 7% | 9% |

Substituting in Equation 22:

$$Q = 0.49 \times 10 \times 70\left[\left(\frac{123.7 + 120}{2}\right) - 40\right] = 28{,}100 \text{ Btu per hour.}$$