values obtained from a number of tests made on each type of material, also that all variables due to differences in thickness, pipe sizes, and air conditions are eliminated. Individual manufacturer's materials, will of course, vary in conductivity to some extent from these values.

The heat losses through six of the types of insulation given in Table 8 for 1, 1½ and 2 in. thick materials, and for temperatures commonly encountered in engineering practice can be obtained from Tables 9 to 14 inclusive. The loss through other thicknesses of the materials, and for other hot water or steam temperature conditions may be obtained by interpolation. The heat loss coefficients given in Tables 9 to 14 are based on the conductivities in Table 8 and were computed from data given in Chapter 22, THE GUIDE 1931.

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 shown for bare surfaces, because of the fact that air flowing over the surface of the insulation can increase only the rate of heat transfer from surface to air, and cannot change the internal resistance to heat flow inherent in the insulation itself. The maximum increase in loss due to air velocity ranges from about 30 per cent in the case of 1 in. thick insulation, to about 10 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 sealed as tightly as possible. Pipe insulation out-of-doors should be provided with a waterproof jacket, and other outdoor insulation should be thoroughly weatherproofed.

HEAT LOSSES FROM DUCTS

The heat transmission through sheet metal duct walls is mainly a function of the surface character of the metal since the thickness of the metal itself is not enough to appreciably retard the flow of heat. In other words, the two surfaces provide the resistance to heat flow through the metal. The surfaces of black iron probably offer the least resistance to the flow of heat, while metals with brighter and smoother surfaces, offer greater resistance. For ducts in service at normal air velocities and temperatures, the coefficient of heat transmission for black iron is 1.6 Btu per square foot per hour per degree Fahrenheit difference between the mean temperature in the duct and the temperature of the surrounding air and for galvanized iron is 1.1 Btu per square foot per hour per degree Fahrenheit difference.

The heat loss from a given length of duct is expressed by:

$$H = k\,P\,L\left[\left(\frac{t_1 + t_2}{2}\right) - t_3\right] \qquad (1)$$

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

$$H = 0.24\,M\,(t_1 - t_2) = 14.4\,A\,V\,d\,(t_1 - t_2) \qquad (2)$$

Equating 1 and 2 enables the determination of the temperature drop in the duct:

$$k\,P\,L\left[\left(\frac{t_1 + t_2}{2}\right) - t_3\right] = 14.4\,A\,V\,d\,(t_1 - t_2)$$

$$\frac{t_1 + t_2 - 2t_3}{t_1 - t_2} = \frac{28.8\,A\,V\,d}{k\,P\,L} \qquad (3)$$

where

- H = heat loss through duct walls, Btu per hour.
- k = overall heat transmission coefficient, Btu per square foot per hour per degree Fahrenheit temperature difference.
- P = perimeter of duct, feet.
- L = length of duct, feet.
- t_1 = temperature of air entering duct, degrees Fahrenheit.
- t_2 = temperature of air leaving duct, degrees Fahrenheit.
- t_3 = temperature of air surrounding duct, degrees Fahrenheit.
- M = weight of air per hour through the duct, pounds.
- A = cross-sectional area of duct, square feet.
- V = velocity of air in the duct, feet per minute, at specified temperature.
- d = density of air at the specified temperature at which V is measured.

In using the Formula 3 one of the duct air temperatures will be unknown and will be solved for by substitution of the other known or assumed values. The assumed values dependent upon the mean duct air temperature can be determined exactly by cut and try. A more exact formula[2] is available for determining the heat loss from a duct in case the duct is exceedingly long.

Heat losses for insulated ducts are given in the warm air column of Table 15. The losses are based on a uniform series of material conductivities at 86 F mean temperature and an air temperature of 50 F outside of the duct. The losses may be interpolated for odd material conductivities and temperatures. The conductivities of various materials will be found in Table 2 of Chapter 5. For cases where the surrounding air temperature is other than 50 F the losses may be selected on the basis of temperature difference.

Example 1. Determine the entering air temperature and heat loss for a duct 24 x 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. Assume the entering air temperature to be 130 F. Thus the mean temperature difference will be 85 F. Referring to the warm air column of Table 15 and interpolating for 90 F temperature difference, the overall heat transmission coefficient is found to be 0.516 Btu. From Table 4, Chapter 1 the density of air at 70 F and 29.92 in. Hg. is found to be 0.07423 lb per cubic foot. Substituting these and the other given values in Formula 3,

$$\frac{t_1 + 120 - (2 \times 40)}{t_1 - 120} = \frac{28.8 \times 6 \times 1200 \times 0.07423}{0.516 \times 10 \times 70}$$

$$t_1 + 120 - 80 = 42.62\,(t_1 - 120)$$

$$t_1 + 40 = 42.62\,t_1 - 5114$$

$$5154 = 41.62 t_1$$

$$123.8 = t_1$$

[2]Performance Tests of Asbestos Insulating Duct, by R. H. Heilman and R. A. MacArthur (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, February, 1938, p. 127).