

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 exposed to the elements should be thoroughly waterproofed.

Example 3. 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. 2, the coefficient for 1 in. magnesia on a 2 in. pipe is found to be 0.285 Btu per hour per linear foot of pipe per degree temperature difference at a temperature difference of 169.4 F. The total hourly loss per linear foot of pipe will then be $0.285 \times 169.4 = 48.3$ Btu. The total annual loss through the insulation = 48.3×165 (linear feet) $\times 4000$ (hours) = 31,900 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 $181,600 - 31,900 = 149,700$ 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) $\times 149.7$ (thousand Mb) = \$120.36, or 82.4 per cent of the cost when using uninsulated pipe.

TABLE 14. PIPE COVERING FACTORS

TYPES OF INSULATING MATERIALS	TEMPERATURE DIFFERENCE, PIPE TO AIR, DEG F					
	100	200	300	400	500	600
85 per cent Magnesia Type.....	1.050	1.024	0.997	0.971	0.944	0.918
Corrugated Asbestos Type.....	1.425	1.465	1.505	1.545	-----	-----
(4 Plies per 1 in. thick)						
Corrugated Asbestos Type.....	1.435	1.437	1.438	1.440	-----	-----
(8 Plies per 1 in. thick)						
Laminated Asbestos Type.....	0.969	0.960	0.951	0.942	0.933	0.924
(30-40 Laminations per 1 in. thick)						
Laminated Asbestos Type.....	1.103	1.104	1.105	1.106	1.107	1.108
(14-20 Laminations per 1 in. thick)						
Mineral Wool Type.....	1.023	1.028	1.033	1.038	1.043	1.048
High Temperature Type.....	1.560	1.489	1.418	1.347	1.276	1.205
(Diatomaceous Earth and Asbestos)						
Brown Asbestos Type.....	1.003	0.997	0.990	0.984	0.977	0.971
(Felted Fiber)						

HEAT LOSSES FROM DUCTS

The thermal transmission coefficient U for an uninsulated metal duct can be obtained from the equation:

$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o}} \quad (4)$$

where

U = thermal transmittance, Btu per square foot per hour per degree Fahrenheit difference in temperature between the average temperature inside the duct and the air outside the duct.

f_i = film conductance inside the duct, Btu per hour per square foot per degree Fahrenheit.

f_o = film conductance outside the duct, Btu per hour per square foot per degree Fahrenheit.

Film conductance f_i for air flowing in ducts apparently depends only on the velocity of the air and the diameter of the duct. A fairly reliable inside coefficient can be calculated from Schultz's modified equation:

$$f_i = \frac{0.32 V_o^{0.8}}{D^{0.25}} \quad (5)$$

where

V_o = velocity of air in duct, feet per second.

D = diameter of duct, feet.

Film conductance f_o depends on a number of variables including temperature, diameter, and emissivity of the outer surface. Conductance f_o can be readily calculated from Tables 1, 2, 3, 4, and 5. From this explanation, it is seen that it is unwise to recommend a given value of U for all uninsulated metal ducts.

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

$$Q = UPL \left[\left(\frac{t_1 + t_2}{2} \right) - t_3 \right] \quad (6)$$

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

$$Q = 0.24 M (t_1 - t_2) = 14.4 A V d (t_1 - t_2) \quad (7)$$

Equating 6 and 7 enables the determination of the temperature drop in the duct:

$$\frac{t_1 + t_2 - 2t_3}{t_1 - t_2} = \frac{28.8 A V d}{UPL}$$

Let $x = \frac{28.8 A V d}{UPL}$ for rectangular ducts, $= \frac{7.2 D V d}{UL}$ for round ducts, solving for t_1 and t_2 :

$$t_1 = \frac{t_2 (x + 1) - 2t_3}{(x - 1)} \quad (8)$$

$$t_2 = \frac{t_1 (x - 1) + 2t_3}{x + 1} \quad (9)$$

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

$$t_1 = \frac{t_1 - t_2}{\epsilon \left(\frac{UPL}{14.4 A d V} \right)} + t_3 \quad (10)$$

In these equations

Q = heat loss through duct walls, Btu per hour.

U = thermal transmission coefficient, Btu per square foot per hour per degree Fahrenheit.

P = perimeter of duct, feet.

L = length of duct, feet.

t_1 = temperature of air entering duct, degree Fahrenheit.

t_2 = temperature of air leaving duct, degree Fahrenheit.

t_3 = temperature of air surrounding duct, degree Fahrenheit.

M = weight of air per hour, through the duct, pounds.

A = cross-sectional area of duct, feet.