For uninsulated non-metallic ducts,

$$U = \frac{1}{\frac{1}{f_i} + \frac{x}{k} + \frac{1}{f_o}} \tag{21}$$

where

U = overall coefficient of heat transfer, Btu per (hour) (square foot) (Fahrenheit degree).

f_i = surface conductance (inside) Btu per (hour) (square foot) (Fahrenheit degree).

f_o = surface conductance (outside) Btu per (hour) (square foot) (Fahrenheit degree).

x = thickness, inches.

k = unit conductivity of material, Btu per (hour) (square foot) (Fahrenheit degree per inch thickness).

TABLE 11. WEIGHTS AND THICKNESSES OF STANDARD COPPER SHEETS[a]
Rolled to Weight

Weight per Square Foot		Thickness, Inches		Nearest Gage No.		
Ounces	Pounds	Decimal Equivalent	Nearest Fraction	B. & S.	Stubs	U. S. Std.
10	0.625	0.0135	1/64	27	29	29
12	0.750	0.0162	1/64	25	26	26
14	0.875	0.0189	1/64	23	24	25
16	1.000	0.0216	1/64	22	23	24
18	1.125	0.0243	1/64	21	22	23
20	1.250	0.0270	1/64	20	21	22
24	1.500	0.0324	1/64	19	20	20
28	1.750	0.0378	1/64	17	19	19
32	2.000	0.0432	3/64	16	18	18
36	2.250	0.0486	3/64	15	17	17
40	2.500	0.0540	3/64	15	17	17
44	2.750	0.0594	1/16	14	16	16
48	3.000	0.0648	1/16	13	15	14
56	3.500	0.0756	1/16	11	14	13
64	4.000	0.0864	1/16			

[a]Variations from these weights must be expected in practice.

Where x is small and k is large, however, the factor $\frac{x}{k}$ is of little importance and may be neglected.

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:

$$f_i = \frac{0.32v^{0.8}}{D^{0.25}} \tag{22}$$

where

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

D = inside diameter of duct, feet.

Film conductance f_o depends on a number of variables including temperature, diameter, and emissivity of the outer surface, and can be calculated from data in Chapter 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:

$$Q_w = UPl\left[\left(\frac{t_1 + t_2}{2}\right) - t_3\right] \tag{23}$$

where

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

P = perimeter of duct, feet.

l = length of duct, 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:

$$Q_w = 0.24w(t_1 - t_2) = 14.4AV_m\rho_v(t_1 - t_2) \tag{24}$$

where

w = weight of air through duct, pounds per hour.

A = cross-sectional area of duct, square feet.

V_m = mean velocity of fluid, feet per minute.

ρ_v = density of air at specified temperature at which velocity V_m, is measured pounds per cubic foot.

Equating (23) and (24):

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

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:

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

$$t_2 = \frac{t_1(y - 1) + 2t_3}{(y + 1)} \tag{26}$$

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

$$t_2 = \frac{t_1 - t_3}{e^z} + t_3 \tag{27}$$

where

$z = \frac{UPL}{14.4A\rho_vV_m}$.

e = Naperian base of logarithms = 2.718.

In using Equations 25, 26, and 27, 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. 16. 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 9. For cases where the mean temperature is other