2. For ducts run underground an allowance shall be made based on the estimated heat loss of the duct, assuming the average temperature of the ground to be 55 F.

3. For galvanized ducts with the usual ranges of air temperature and velocity, the coefficient of heat transmission may be taken as 1.7 Btu per hour per degree difference between the mean temperature of the air in the duct and that surrounding the duct.

The heat loss may then be expressed by

$$H = 1.7\ \pi\ DL\left[\left(\frac{t_i + t_y}{2}\right) - t_o\right] \tag{7}$$

and also by

$$H = 0.24\ M\ (t_i - t_y) = 60\ \frac{\pi}{4}\ D^2 Vd \times 0.24\ (t_i - t_y) \tag{8}$$

Equating (7) and (8)

$$1.7\ \pi\ DL\left[\left(\frac{t_i + t_y}{2}\right) - t_o\right] = 3.6\ \pi\ D^2 Vd\ (t_i - t_y)$$

$$\frac{t_i + t_y - 2t_o}{t_i - t_y} = \frac{4.235\ DVd}{L} \tag{9}$$

where

H = heat loss from the duct, Btu per hour.
D = diameter of duct, feet.
L = length of duct, feet.
t_i = temperature of air entering the duct.
t_y = temperature of air leaving the duct.
t_o = temperature of air surrounding the duct.
M = weight of air passing a given cross section of the duct per hour.
V = velocity of air in the duct, feet per minute, at specified temperature.
d = density of the air at the specified temperature at which V is measured.

Usually all the values in Formula 9 may be approximated except t_i, the initial or entering temperature, which can be readily found where the others are known or assumed.

Example 4. Determine the temperature drop in a galvanized duct 20 in. diameter and 60 ft long carrying air at a velocity of 1200 fpm measured at 70 F, to be delivered at a temperature of 140 F when the air surrounding the duct is at a temperature of 50 F.

Solution. Substituting in Formula 9,

$$\frac{t_i + 140 - (2 \times 50)}{t_i - 140} = \frac{4.235 \times 1.666 \times 1200 \times 0.07492}{60}$$

$$t_i = 158.7\ \text{F}$$

$$\text{temperature drop} = 158.7 - 140 = 18.7\ \text{F}$$

Example 5. An uninsulated 12 in. diameter galvanized duct extends 50 ft through an unconditioned room to supply 80 F cool air to an adjacent space. If the average temperature of the air surrounding the duct in the unconditioned room is 100 F and the velocity of the air through the duct is 1000 fpm, measured at 70 F, determine the temperature gain which must be allowed in passing the air through the unconditioned room.

Solution. Substituting in Formula 9,

$$\frac{t_i + 80 - (2 \times 100)}{t_i - 80} = \frac{4.235 \times 1.0 \times 1000 \times 0.07492}{50}$$

$$t_i - 120 = 6.34\ (t_i - 80)$$

$$-5.34\ t_i = 120 - 507$$

$$t_i = 72.3\ \text{F}$$

$$\text{temperature gain} = 80 - 72.3 = 7.7\ \text{F}$$

Therefore, air having a temperature of 72.3 F must be introduced at the end of the 50 ft duct in order to supply 80 F air to the conditioned space.

Heat Supplied Heating Units and Washer

The following cases may arise in practice:

A. The heating of the building is done entirely by means of a central fan system, all of the air being drawn from the outside.

B. Similar to *A*, except that all of the air is recirculated.

C. A portion of the air is recirculated, and the remainder is drawn in from the outside.

D. Air at the same temperature is to be delivered to all the rooms. A constant relative humidity is maintained in the building and all of the air circulated is drawn from outside the building. (Not applicable to the heating of various rooms where individual control of each room is desired.)

E. Outside air, return air, and by-pass air are used with the reheater located in by-pass air chamber.

F. Arrangement of apparatus where individual control of the temperature for each room is required in conjunction with air washer equipment to maintain a constant relative humidity in the rooms. The air washer is provided with a water heater for the spray water, capable of fully saturating the air. A section of preheater may be used for this purpose in place of the water heater. With this arrangement and with a uniform temperature of air entering the rooms, it is impossible to maintain the same room temperature throughout the building because the weight of air to be delivered to each room is determined and fixed by the ventilating requirements.

In analyzing these cases, the following symbols will be used:

H = heat loss of the room or building, Btu per hour.
H_1 = heat to be supplied to the reheater coil, Btu per hour.
H_2 = heat supplied tempering coil, or tempering coil and preheater, Btu per hour.
H_3 = heat supplied air washer by water heater, Btu per hour.
H_4 = heat to be supplied booster coil, Btu per hour.
M = weight of air to be introduced into the room or building, pounds per hour.
M_r = weight of recirculated air, pounds per hour.
M_b = weight of air by-passing washer, pounds per hour.
M_o = weight of air drawn in from outside, pounds per hour.
t_o = mean temperature of outside air, degrees Fahrenheit.
t = mean air temperature to be maintained in the room or building, degrees Fahrenheit.
t_1 = mean temperature of the air entering the reheater coil.
t_2 = mean temperature of the air leaving the reheater coil.
t_z = temperature loss in the duct system.
t_y = temperature of the air leaving the duct outlets.
t_x = average temperature of air entering tempering coil.
t_w = temperature of air entering washer.
0.24 = specific heat of air at constant pressure.