Using the same illustration and assuming that a humidifying air washer is used with a water heater, the tempering coil will simply have one stack, section or tube row deep to raise the air temperature to about 35 deg. from zero outside temperature. The hot water sprays in the air washer will saturate this air at a temperature of 41 deg. and the reheater will simply raise this temperature to any point required to maintain a room temperature of 70 deg. and a relative humidity of 35 per cent.

The amount of heat to be furnished by the water heater in connection with the humidifying air washer is made up of the sum of two factors—*First:* to heat the specified air volume from the temperature leaving the tempering coil to the saturated air temperature leaving the washer, and *Second:* to evaporate sufficient moisture into this air to saturate it at the temperature required.

If only 23 per cent relative humidity is desired in the room in connection with 70 deg. dry bulb temperature, the temperature entering the air washer, without water heater will be 64 deg. dry bulb, and the temperature leaving the air washer will be 48 deg. dry bulb, which is a drop of 16 deg. through the washer or 67 per cent of 23½ deg. difference between 64 deg. dry bulb and the corresponding 40½ deg. wet bulb temperature.

The illustration in connection with Case 4 indicates that this arrangement is used entirely for heating the room by the fan system. In many cases the heat losses in a room or building are taken care of entirely by direct radiation, and in such cases the final temperature of the air leaving the heater will probably be in the neighborhood of 80 deg. In such a case the same arrangements of tempering coils and reheaters will be used. The arrangement shown in the diagram contemplates the same air temperature being delivered to all rooms on this system, and will not be applicable to the heating of several rooms where individual control of each room is desired.

Case 5—When a portion (M_o) of the air circulated is drawn from the outside and the remaining M_r recirculated air, the air drawn from the outside is passed through a tempering coil and the mixture of air, from the outside and recirculated air, being passed through an air washer or humidifier and a reheater.

Similar conditions will apply to Case 5 as have been outlined for Case 4 except that a percentage of recirculated air at a different dry and wet bulb temperature and a different percentage of relative humidity will be mixed with the fresh air after it has been warmed by the tempering coil.

In Case 5, (M_o) is known from the ventilation requirements as specified, and the amount of air permitted to be recirculated is, therefore:

$$M_r = \frac{H}{0.24\,(t_y - t)} - M_o \qquad (7)$$

Case 6 (a, b, c)—When all of the air circulated is drawn from the outside, passed through a tempering coil and air washer or humidifier, a portion of the tempered and conditioned air passed through an indirect heater or reheater and a portion of the tempered and conditioned air by-passed around the reheater and the mixture passed into the room or building for heating and ventilating.

The weight of air to be circulated per hour equals (M_o) as determined by the ventilation requirements. The dry bulb temperature of the mixture of tempered and reheated air entering the room or building is to be ascertained by the following formulae:

$$M_o \times 0.24\,(t_y - t) = H \qquad (8)$$

$$t_y = \frac{H + 0.24\,M_o t}{0.24\,M_o} \qquad (9)$$

This case illustrates the arrangement of apparatus when the heating of several rooms is required with individual control of temperature for each room. The arrangement of apparatus, including tempering coil, air washer or humidifier, retempering coil and reheater coil, will be the same as has been outlined in Case 4.

The air leaving the reheater and the air by-passed around the reheater, although having different dry bulb temperatures, will have the same dew-point temperature as the air (t) in the room or building to which the air is delivered and with relative humidity as specified; if no relative humidity is specified it can be assumed as 35 per cent. If no room temperature is specified it should be assumed as 70 deg. The relative weights

of air passed through the reheater and by-passed around the reheater shall be ascertained by the following method:

X = parts of reheated air in mixture.
$(1 - X)$ = parts of tempered air in mixture.
t_y = mean dry bulb temperature of the mixture entering room or building.
t_x = loss of temperature in the duct system.
t_1 = mean dry bulb temperature of the air entering reheater and by-pass.
t_2 = mean temperature of the air leaving the reheater.

$$(X)\,(t_2 + 460) + (1 - X)\,(t_1 + 460) = (t_m + 460) \qquad (10)$$

t_m = mean temperature of air entering the duct system = $(t_y + t_x)$.
SOLVE: for X. Then $M_h = X$

M_h is the weight of air in pounds per hour to be passed through the reheater. The temperature (t_y) will ordinarily be different for each room of the building. The *total weight* of air passed through the reheater will be the sum of the requirements for all the rooms.

Case 7—Indirect system for warming the air drawn in from the outside for ventilating purposes only. (When an indirect system is employed to warm the air drawn into the system from the outside for ventilating purposes only, the heat loss is provided for by direct radiation or by some other means).

The weight of air to be circulated per hour is (M_o) as may be determined from the specified ventilation requirement $M_h = M = M_o$. The temperature of the air delivered to the room (t_y) shall be assumed 5 deg. higher than room temperature (t) specified.

a. If no air-conditioning apparatus is to be employed the arrangement is similar to *Case 2* where $t_1 = t_o$ and $t_y = t + 5$.

b. If air-conditioning apparatus is to be employed the arrangement is similar to *Case 4; $M_h = M = M_o$*.

Loss of Temperature in Duct Systems (t_x):

a. When the indirect heater and duct system, are located in the enclosure to which the air is to be delivered, it may be assumed that there is no loss of temperature between the indirect heater and the point or points of discharge into the enclosure. $t_x = 0$.

b. For gravity indirect heating, a loss in air temperature of 5 deg. for the first floor, 8 deg. for the second floor, and 10 deg. for the third floor between the indirect radiator and room register can be assumed.

c. For ducts run underground an allowance must be made based on the estimated heat loss of the duct, assuming an average temperature of the ground of 55 deg. fahr.

d. For ducts run in outside walls to the second floor and above, a loss of not less than 10 deg. shall be used in the calculations.

When the heating and ventilation requirements have been found the size of the heater and fan are calculated for a given friction, temperature range, pressure loss in ducts, etc. Pressure losses build up rapidly as velocities are increased and generally vary approximately as the square of the velocity. The allowable pressure loss through the heater should in general not exceed 50 per cent of the total static pressure of the system. In public building practice allowable pressure loss through tempering coils and reheaters should be under ½ in. of water and when an air washer is used the friction through the tempering coil and reheater should not exceed 40 per cent of the total resistance as a rule.

For data on design and construction of ventilating duct systems, see Chapter XXVIII.