If any one of these nine basic requirements for the successful performance of a heating plant is below par, it is enough to cause failure of a heating plant that otherwise would be a success. A heating plant is like a chain that is no stronger than its weakest link.

STRIKING A HEAT BALANCE

The engineer in designing a heating system must strike a balance between the output or heat loss from the building and the input of heat from the system and boiler principally. The output falls under three classifications; infiltration, transmission, and line losses. The proper input depends upon the proper size and type of radiators, the proper design and sizes of piping and valves, and the proper capacity and type of boiler installed. The correct balance of these six major factors means a properly installed heating system, and with proper and intelligent operating conditions will give efficient performance.

The total heat the heating apparatus must furnish, includes the total heat loss plus a heating-up-factor.

The heating-up-factor is determined by the rate at which initial heat is required to raise the temperature of the cold building and its contents to a desired degree in a given time.

For actual practice the heating-up-factor can be added to the infiltration losses and expressed in terms of air changes.

The number of air changes per hour which will occur in a room, depends on its construction, exposure, number and type of windows, doors, etc. Air changes for average conditions, without providing for ventilation, can be figured as follows:

Rooms, 1 side exposed	=1	Air change per hr.
" 2 " "	=1½	" " " "
" 3 " "	=2	" " " "
" 4 " "	=2	" " " "
Entrance halls	=2 to 3	" " " "
Reception halls	=2	" " " "
Living rooms	=1 to 2	" " " "
Dining rooms	=1 to 2	" " " "
Bath rooms	=2	" " " "
Drug stores	=2 to 3	" " " "
Clothing stores	=1	" " " "
Churches, Factories, Lofts, etc.	=1 to 3	" " " "

To heat 1 cu. ft. of air 1 deg. fahr. requires 0.02 B.t.u., then the cubic contents of a room times the number of air changes times 0.02 times the difference in temperature between the outside and inside (for which the system is designed), will give the number of B.t.u. required for heating up and infiltration. This added to the transmission losses gives the total B.t.u. required for heating.

HEAT LOSSES FROM BUILDINGS

INFILTRATION

INFILTRATION losses are due to the leakage of cold air into and warm air out of the building. Those losses are figured either on a basis of the number of air changes per hour or on a basis of window leakage (Table 1). The infiltration losses depend upon the nature and tightness of the building construction, the lineal feet of window and door cracks, the amount of air admitted for ventilation, the presence of open fireplaces, and vent registers, and the air admitted by opening and closing of doors and other openings.

Infiltration losses can be materially reduced by the use of storm doors and windows, metal weather strips on doors and windows, by calking around door and window casings, and in frame construction by close fitting tongue and groove siding covered with heavy building paper, and by the use of plaster board in place of lath. The infiltration loss through brick walls is usually high, while that through hollow tile walls is very high due to the many chipped openings and the thin plaster bearing points where the ends of tile abut. Besides the wind factor in transmission, the high infiltration loss in windy weather is the reason, according to Whitten and March, (See A. S. H. & V. E. TRANSACTIONS, Vol. 22, p. 195), that it is as difficult to heat an exposed room at 20 deg. above zero with a 35-mile wind blowing, as it would be to heat the same room at 20 deg. below zero with no wind blowing. Strong winds very seldom prevail at temperatures below 15 deg. above zero. The drop in temperature for each mile wind velocity is given in Table 11 and it can readily be seen that this matter of wind velocity must receive careful consideration in planning and designing a house heating plant that will render efficient service in all weather conditions.

This cold air entering through the building construction cracks, and crevices, windows, etc. is a load that the heating plant must meet and each installation presents a particular problem in this respect.

The cold air leaking into the room must be heated from the temperature of the outside air to that of the room temperature. One cubic foot of air at zero weighs 0.086 lb. (GUIDE, 1922, p. 166), while at 70 deg. 1 cu. ft. of air weighs only 0.075 lb. Therefore, 0.87 cu. ft. of air leakage into a room at 0 deg. becomes 1 cu. ft. of air at the room temperature of 70 deg. The specific heat of air at constant pressure, or the number of heat units required to raise 1 lb. of air 1 deg., is 0.2415. To raise 0.87 cu. ft. of air which weighs 0.075 lb. only 1 deg., requires $0.075 \times 0.2415 = 0.0181$ heat units, and to raise it 70 deg. from zero to room temperature, requires $70 \times 0.0181 = 1.267$ heat units.

In every day practice of figuring, the approximate value of 0.02 heat units per cu. ft. per deg. rise in temperature is used in place of 0.0181. Therefore, in order to obtain the heat loss due to infiltration multiply together these four factors; (1) contents of room in cubic feet