Sensible Heat Loss

The formula for the heat required to warm the outdoor air which enters a room by infiltration to the temperature of the room, is given in Equation 5:

$$H_s = 0.240\ Q\rho(t_i - t_o) \qquad (5)$$

where

H_s = heat required to raise temperature of air leaking into building from t_o to t_i, Btu per hour.
0.240 = specific heat of air.
Q = volume of outdoor air entering building, cubic feet per hour (see Chapter 25).
ρ = density of air at temperature t_o, pounds per cubic foot.

It is sufficiently accurate to use $\rho = 0.075$, in which case Equation 5 reduces to:

$$H_s = 0.018\ Q(t_i - t_o) \qquad (5a)$$

The volume Q of outdoor air entering per hour depends on the wind speed and direction, the width of crack or size of openings, the type of openings, and other factors, as explained in Chapter 25. The two methods generally used to obtain the quantity of infiltration air are the crack method and the air change method. The crack method is very indefinite, since it must be based on a number of assumptions. Consequently, the air change method is preferred, even though the accuracy may not be any better. Where the crack method is used for estimating leakage, it is more convenient to express the air leakage heat loss in terms of the crack length:

$$H_s = BL(t_i - t_o) \qquad (5b)$$

where

B = air leakage per (hour) (foot of crack) (see Chapter 25) for the wind velocity and type of windows or door crack involved, multiplied by 0.018.
L = length of window or door crack to be taken into consideration, feet.

Example 5: What is the infiltration heat loss per hour through the crack of a 3 × 5 ft average, double-hung, non-weatherstripped, wood window, based on a wind speed of 15 mph? Assume indoor and outdoor temperatures to be 70 F and 0 F, respectively.

Solution: According to Table 2, Chapter 25, the air leakage through a window of this type (based on 1/16 in. crack and 3/64 in. clearance) is 39 cu ft per (ft of crack) (hour). Therefore, $B = 39 \times 0.018 = 0.70$. The length of crack L is $(2 \times 5) + (3 \times 3)$, or 19 ft; $t_i = 70$ and $t_o = 0$. Substituting in Equation 5b:

$$H_s = 0.70 \times 19 \times (70 - 0) = 931 \text{ Btu per hour.}$$

Crack Length to be Used for Computations

For designers who prefer to use the crack method, the basis of calculation is as follows: The amount of crack used for computing the infiltration heat loss should be not less than half of the total length of crack in the outside walls of the room. For a building having no partitions, air entering through the cracks on the windward side must leave through the cracks on the leeward side. Therefore, take one-half the total crack for computing each side and end of the building. In a room with one exposed wall, take all the crack; with two exposed walls, and with three or four exposed walls, take the wall having the crack that will result in the greater air leakage; but in no case take less than half of the total crack.

In small residences the total infiltration loss of the house is generally considered to be equal to the sum of the infiltration losses of the various rooms. However, this is not necessarily accurate, as at any given time infiltration will take place only on the windward side or sides and not on the leeward side. Therefore, for determining the total heat requirements of larger buildings, it is more accurate to base the total infiltration loss on the wall having the most total crack, but in no case on less than half of the total crack in the building.

Number of Air Changes to be Used for Computations

Since a certain amount of judgment is required regarding quality of construction, weather conditions, use of the room, and other factors in estimating infiltration by any method, some designers base infiltration upon an estimated number of air changes rather than upon the length of window cracks. Table 1 of Chapter 25 indicates air changes commonly used, but should be taken only as a guide.

When calculating infiltration losses by the air change method, Equation 5a may be used by substituting for Q the volume of the room multiplied by the number of air changes obtained from Table 1, Chapter 25. For further discussion of the method see section on Air Change Method in Chapter 25.

Latent Heat Loss

When it is intended to add moisture to air leaking into a room in order to maintain proper winter comfort conditions, it is necessary to determine the heat required to evaporate the water vapor added. This heat may be calculated by:

$$H_1 = Q\rho(W_i - W_o)h_{fg} \qquad (6)$$

where

H_1 = heat required to increase moisture content of air leaking into building from W_o to W_i, Btu per hour.
Q = volume of outdoor air entering building, cubic feet per hour.
ρ = density of air at temperature t_i, pounds per cubic foot.
W_i = humidity ratio of indoor air, pounds per pound of dry air.
W_o = humidity ratio of outdoor air, pounds per pound of dry air.
H_{fg} = latent heat of vapor at W_i, Btu per pound.

If the latent heat of vapor h_{fg} is assumed to be 1060 Btu per lb, Equation 6 reduces to:

$$H_1 = 79.5\,Q(W_i - W_o) \qquad (6a)$$

Equations 5a, 5b, and 6a may also be used for determining the sensible and latent heat gains due to infiltration in cooling load computations.

SELECTION OF WIND SPEEDS

The effect of wind on the heating requirements of any building should be given consideration for two reasons:

1. Wind movement increases the heat transmission of walls, glass, and roof, affecting poor walls to a much greater extent than good walls.
2. Wind materially increases the infiltration of cold air through the cracks around doors and windows, and even through the building materials themselves (see Tables 2 and 3, Chapter 25).

Theoretically, as a basis for design, the most unfavorable combination of temperature and wind speed should be chosen. It is entirely possible that a building might require more heat on a windy day with a moderately low outdoor temperature, than on a quiet day with a much lower outdoor temperature. However, that combination of wind and temperature which is the worst would differ with different buildings, because wind speed has a greater effect on buildings which have relatively high infiltration losses. It would be possible to compute the heating load for a building for several different combinations of temperature and wind speed which records show to have occurred, and to select the worst combination, but designers generally do not feel that such a degree of refinement is justified.

A complete correlation between the design temperatures in Column 6 of Table 1, and the simultaneous maximum wind speed has not been made at the present time. If a designer prefers the air change method for computing infiltration load, such correlation is not too important. Designers who use the crack method may use a leakage rate at 15 mph wind speed, unless local experience has established that other speeds are more appropriate. Abnormally high wind speed may have significant effect on the transmission coefficient U. (See Table 20, Chapter 24.)

Exposure Factors

Many designers use empirical *exposure* factors to increase the calculated heat loss of rooms or spaces on the side or sides of the building exposed to the prevailing winds. However, the use of exposure factors is unnecessary when the method of calculating heat losses described in this chapter is used. They may be regarded as *factors of safety* for the rooms or spaces exposed to the prevailing winds, to allow for additional capacity for these rooms or spaces, or to *balance the radiation*, particularly in the case of multistory buildings. Tall buildings may have severe infiltration heat losses, induced by their stack effect (see Chapter 25), that will require special consideration. Although the exposure allowance frequently is assumed to be 15 percent, the actual allowance to be made, if any, must, to a large extent, be a matter of experience and judgment of the designer, since there are no authentic test data available from which rules could be developed for the many conditions encountered in practice.

AUXILIARY HEAT SOURCES

The heat supplied by persons, lights, motors, and machinery should always be ascertained in the case of theaters, assembly halls, industrial plants, and commercial buildings such as stores, office buildings, etc., but allowances for such heat sources must be made only after careful consideration of all local conditions. In many cases, these heat sources may materially affect the size of the heating plant and may have a marked effect on the operation and control of the system. In any evaluation, however, the night, week-end, and any other unoccupied periods must be evaluated. In general, where audiences are present, the heating system must have sufficient capacity to bring the building to the stipulated indoor temperature before the audience arrives. In industrial plants, quite a different condition exists, and heat sources, if always available during occupancy, may be substituted for a portion of the heating requirements. In no case should the actual heating installation (exclusive of heat sources) be reduced below that required to maintain at least 40 F in the building.

Table 7 .... Heat Equivalents of Various Sources[a,b]

Machinery (Motor in room)	= MotorHp/efficiency × 2544 Btuh
Machinery (Motor outside room)	= Motor Hp × 2544 Btuh
Electric Lights	= Killowatts × 3413 Btuh
Gas (Producer = 150) (Manufactured = 535) (Natural = 1000) Btu/cu ft	

[a] Additional values are given in Chapter 27, Table 27.
[b] Ballasts of fluorescent tubes must be included if located in conditioned space.

Electric Motors and Machinery

Motors and the machinery which they drive, if both are located in the room, convert all of the electrical energy supplied into heat. This heat is retained in the room if the product manufactured is not removed until its temperature is the same as the room temperature.

If power is transmitted to the machinery from the outside, then only the heat equivalent of the brake horsepower supplied is used. In some mills this is the chief source of heating, and it is frequently sufficient to overheat the building even in zero weather, thus requiring cooling by ventilation the year round. Table 7 shows the heat output equivalent of various sources of heat in a factory. For information concerning the heat supplied by persons, refer to data given in Chapter 7 and Table 26, Chapter 27. For appliances see Table 27, Chapter 27.

INTERMITTENTLY HEATED BUILDINGS

In the case of intermittently heated buildings, additional heat is required for raising the temperature of the air, the building materials, and the material contents of the building to the specified indoor temperature. The rate at which this

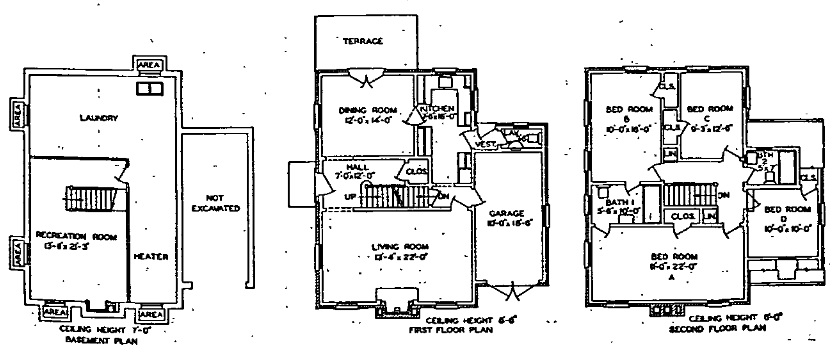

Fig. 1 .... Floor Plans of Residence