Where irregular conditions are involved it may be desirable to actually calculate the fuel required to warm the building structure and contents for the number of times during the heating season the heating plant would not be in operation and to add this quantity to the fuel required for the number of hours during which the building is heated. The greater the heat capacity of the structure the greater will be the relative importance of this item. For structures of low heat capacity, such as frame buildings, this factor usually may be neglected.

Example 1. A small factory building located in Philadelphia is to be heated to 60 F between the hours of 7 a.m. and 7 p.m., and to 50 F during the remaining hours. The calculated hourly heat loss, based on a design temperature of − 6 F, is 500,000 Btu. If coal having a calorific value of 12,500 Btu per pound is fired, and the over-all heating efficiency is assumed to be 60 per cent, how many tons of coal will be required for a normal heating season, neglecting other heat sources and any loss of heat through open windows?

Solution. Since there are no partitions in this building, the entire heat loss is considered. The average outside temperature during the heating season t_a is 41.9 F (see Table 2, Chapter 7); $t = 60$ F; $N = 5040$; $H = 500{,}000$; $(t - t_o) = 66$ F; $C = 12{,}500$; $E = 0.60$. Substituting these values in Equation 1 and dividing by 2000 to change to tons:

$$F = \frac{500{,}000 \times 18.1 \times 5040}{66 \times 12{,}500 \times 0.60 \times 2000} = 46 \text{ tons of coal}$$

Inasmuch as the building will be heated to 50 F at night, the average inside temperature at the breathing line will be 55 F, and the percentage saving will be $\frac{60 - 55}{60 - 41.9}$ = 0.276 or 27.6 per cent. The net fuel consumption will therefore be 46 − 0.276 × 46 or 33.3 tons.

MISCELLANEOUS FACTORS

There are many factors which would be likely to affect the theoretical fuel requirements of a building, such as the opening of windows, abnormal inside temperatures, other heat sources, sun effect, wind, and rain. In many cases it is difficult to evaluate these factors accurately, particularly in the case of open windows, and the results are correspondingly less accurate. The degree of refinement of the calculations should, of course, be consistent with the conditions involved. If the heat loss from the boiler and piping does not warm the building or is not included in H, the proper allowance should be made. In selecting a boiler, this allowance is frequently assumed to be 25 per cent of the total heat loss of the building, but in estimating fuel requirements, the more accurate procedure of computing the pipe and boiler losses should be used, unless this item is likely to be outweighed by other less tangible factors.

Where temperature control is installed the fuel consumption can obviously be predetermined with greater accuracy than where no such control has been provided. In fact the calculated requirements agree to a remarkable extent in many cases with the actual fuel consumption. This has been particularly true of gas-fired installations, with which effective temperature regulation usually is possible.

OTHER HEAT SOURCES

Where other heat sources are available it is quite often possible to make accurate allowance for the reduction in the fuel consumption resulting

therefrom. These sources include the heat supplied by persons, lights, motors and machinery, and should also be ascertained in the case of theaters, assembly halls and industrial plants. (See Chapter 7.) In many cases these heat sources should not be allowed to affect the size of the installation of heating equipment, although they may have a marked effect upon the fuel consumption. In residences this factor usually may be neglected.

DEGREE-DAY METHOD

A very useful unit for estimating fuel consumption, particularly for residences, is the degree-day. (See definition in Chapter 41.) Degree-days for various cities in the United States and Canada are given in Table 1. The term degree-day originated in the gas industry and was later standardized by the *American Gas Association*[3].

The base of 65 F is used for an inside temperature of 70 F. This base was chosen because it was demonstrated, by means of data collected from numerous installations, that heat is seldom supplied to a residence when the outdoor temperature is greater than 65 F. It was also found that the fuel consumed varied almost directly with the difference between 65 F and the outside temperature.

If the inside temperature were maintained at 70 F throughout the 24 hours of the day, then the base of 65 F would probably be in error. It must be borne in mind, however, that although the temperature head is the difference between the inside temperature of say 70 F, and the outside temperature, a lower temperature than 70 F will usually be maintained at night and the base of 65 F will therefore allow for this condition. As already indicated, a temperature of 50 F from midnight to 6 a.m. will reduce the 24-hour average from 70 to 65 F. It is important to note that the degree-day applies specifically to an inside temperature of 70 F, which is the usual temperature for residences, and it should also be noted that allowance is automatically made for the lower nighttime temperature, although this allowance is constant for any given locality.

In Equation 1, the quantity $(t - t_a) \times N$ is equivalent to the number of degree-days D in a heating season multiplied by 24, when the average daily value of t is 65 F. Therefore,

$$(t - t_a) \times N = 24\,D \tag{2}$$

Substituting the value of $(t - t_a) \times N$ from Equation 2 in Equation 1, the following general formula for an average daily inside temperature of 65 F, which is approximately equivalent to an inside daytime temperature of 70 F for residences, is obtained:

$$F_d = \frac{24\,HD}{(t - t_o) \times C \times E} \tag{3}$$

Example 2. The calculated hourly heat loss of a residence located in Chicago is 127,000 Btu, which includes 28,000 Btu for infiltration. The design temperatures are − 8 F and 70 F. The normal heating season is assumed to be 210 days (5,040 hours) and the average temperature during this period is 36.4 F (see Table 2, Chapter 7). The

[3] See *Industrial Gas Series, House Heating (third edition)* published by the *American Gas Association*.