The second method is based on steam consumption data which have been taken from a group of buildings in operation, and the results computed on a degree-day basis. While this method may not be as theoretically correct as the first mentioned method, it is of more value for practical use. Calculations of heat consumption made by the second method will invariably be higher than calculations made by the first method.

Theoretical Estimation Method

To predict the amount of fuel likely to be consumed in heating a building during a normal heating season, it is necessary to know the total heat requirements of the building and the utilization factor of the fuel. The accuracy of the estimate will depend on the ability to select these values and on the care taken in making allowances for other variable factors.

Heat requirements are given by the following general formula:

$$M = \frac{H\,(t - t_a)\,N}{t_d - t_o} \qquad (1)$$

Steam requirements are determined by dividing the above by 1000, thus:

$$S = \frac{H\,(t - t_a)\,N}{(t_d - t_o)\,1000} \qquad (2)$$

Fuel requirements may be determined by the following formula:

$$F = \frac{M}{C \times E} \qquad (3)$$

where

t = inside temperature, degrees Fahrenheit.
t_d = inside design temperature, degrees Fahrenheit.
t_a = average outside temperature, degrees Fahrenheit (Table 2, Chapter 7).
t_o = outside design temperature, degrees Fahrenheit.
H = calculated heat loss of building based on outside temperature (t_o), Btu per hour.
N = number of heating hours per season; 5088 from October 1 to May 1[1].
M = heat loss, Btu per season.
S = steam required to supply M Btu of heat loss.
F = quantity of fuel required per heating season.
C = calorific value of one unit of fuel, the unit being the same as that on which F is based.
E = efficiency of utilization of the fuel, per cent.

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 is fired and the overall heating efficiency is assumed to be 60 per cent, how many pounds of steam would be required for a normal heating season?

[1]This is the period for which t_a (Table 2, Chapter 7) is calculated. If the heating season is different than this period, the corrected values may be substituted for N and t_a.

Solution. Since there are no partitions in the building, the entire heat loss is considered. From Table 2, Chapter 7, the average outside temperature (t_a) during the heating season is 41.9 F; N for the period for which t_a is taken (October 1 to May 1) is 5088; H = 500,000; t_o = −6 F; t = 50 F and 60 F; t_d = 60 F; E = 60 per cent average for heating season; C = 12,500.

The average daily temperature for the 24 hours is:

$$\frac{50 \times 12 + 60 \times 12}{24} = 55 \text{ F}$$

Substituting in Equation 1:

$$M = \frac{500{,}000 \times (55 - 41.9) \times 5088}{60 - (-6)} = 504{,}942{,}000$$

S = 504,942 lb of steam.

$$F = \frac{504{,}942{,}000}{0.60 \times 12{,}500} = 67{,}325 \text{ lb of coal} = 33.7 \text{ tons.}$$

Practical or Degree-Day Method

The amount of heat required by a building depends upon the outdoor temperature, if other variables are eliminated. Theoretically it is proportional to the difference between the outdoor and indoor temperatures. Some years ago the *American Gas Association*[2] determined from experiment in the heating of residences that the gas consumption varied directly as the difference between 65 F and the outside temperature. In other words, on a day when the temperature was 20 deg below 65 F, twice as much gas was consumed as on a day when the temperature was 10 deg below 65 F. The degree day is defined in Chapter 44. Degree-days for various cities in the United States and Canada are given in Table 1.

Establishing the Base Inside Temperature. Recently the *National District Heating Association* has studied the metered steam consumption of 163 buildings[3] in 22 different cities and has published data substantiating the fact that the 65 F base originally chosen by the gas industry is approximately correct.

The steam consumption of each building by months was divided by the number of days in each month, thus giving the average daily steam consumption by months. The average steam consumption was then plotted against the average monthly temperature, as shown in Fig. 1, and the temperature at which a line drawn through the points crossed the base line indicated the temperature corresponding to zero steam consumption, or the base temperature. The composite results from 163 buildings calculated in this manner are shown in Table 2.

The resultant average of 66.0 F is close to the *A.G.A.* figure of 65 F. It will be noted that the base temperature calculated for hotels, apartments and residences is consistently higher than those for such buildings as garages, auto sales buildings, and manufacturing buildings. This, of course, would be expected in view of the higher inside temperatures carried in the former group; in fact, an even greater difference would be

[2]See *Industrial Gas Series, House Heating (third edition)* published by the *American Gas Association.*
[3]These buildings are all served with steam from a district heating company.