*Solution.* Enter Fig. 2 at 260,000 on the upper horizontal scale, move vertically to the 60 per cent efficiency curve, and horizontally to the vertical scale where the firing rate $\left(\frac{H}{EC}\right)$ is found as 3.0 gal per hour.

Substituting this in Equation 2 for $\left(\frac{H}{EC}\right)$:

$$F = 3.0 \times \frac{(70 - 40)\ 5088}{70 - (-5)} = 6106 \text{ gal.}$$

*Example 4.* What would be the total gas consumption over a full heating season of a gas-fired gravity warm air furnace designed according to the Code[1], and with four 12 in. and two 8 in. round leaders to the first floor and six 10 in. leaders to the second floor, if the gas has a heating value of 500 Btu per cubic foot, the plant operates at a 70 per cent seasonal efficiency and is designed to maintain an average inside temperature of 65 F when it is 10 F outside in a city where the average outside temperature is 45 F and the heating season is 5088 hours long?

*Solution.* The area of the round leaders is: 12 in., 113 sq in.; 10 in., 79 sq in.; and 8 in., 50 sq in. From Table 1 the total Btu transmitted is:

| | | |
|---|---|---|
| First Floor: | $[(4 \times 113) + (2 \times 50)] \times 111$ | = 61,272 Btu per hour. |
| Second Floor: | $(6 \times 79) \times 167$ | = 79,158 Btu per hour. |
| | Total | 140,430 Btu per hour. |

Allowing 10 per cent for duct and furnace losses, the gross output would be 154,500 Btu per hour.

Enter Fig. 3 at 154.5 on the upper horizontal scale, move to the 70 per cent efficiency curve and thence to the 500 Btu per cubic foot vertical scale and find $\left(\frac{H}{EC}\right)$ to be approximately 440 cu ft per hour.

Substituting in Equation 2:

$$F = 440 \times \frac{(65 - 45)\ 5088}{(70 - 10)} = 746,428 \text{ cu ft.}$$

## Maximum Rate of Fuel Burning

The rate at which fuel is burned during the maximum, or design hour is frequently useful in setting, or adjusting, the fuel feed devices attached to stokers, oil-burners, and gas burners. This rate is $\left(\frac{H}{EC}\right)$ and can be found from the charts of Figs. 1, 2 and 3 in the same way as outlined in the Examples 3 and 4. In using the charts for this purpose, however, it should be noted that the efficiency ($E$) is the overall efficiency of the boiler or furnace at the time of peak load. This efficiency is generally considerably greater than the value selected for $E$ when the seasonal efficiency of utilization is used in making seasonal fuel estimates. Failure to distinguish between the two essentially different meanings attached to $E$ may result in grossly inaccurate estimates.

The correct fuel burning rate can be determined directly from the several charts for oil or gas burning installations, as these customarily operate on a strictly intermittent basis. These fuel burning devices usually introduce the fuel at a single fixed rate during the *on* periods and this rate should be sufficient to carry the gross or maximum design load. In the case of coal stokers, which are usually capable of variable rates of firing, it is desirable to operate at as low a rate as weather conditions will permit, but the maximum firing rate of the stoker should be sufficient to carry the gross load. This rate may be determined by the same method as used for oil or gas.

*Example 5.* The estimated net load (including domestic hot water supply) as calculated for a residence is 1500 sq ft of hot water radiation. Determine the firing rates for various mechanically fired fuels assuming an overall boiler efficiency of 70 per cent; using coal with a calorific value of 12,500 Btu per pound; No. 3 fuel oil and natural gas having a gross heating value of 1000 Btu per cubic foot.

*Solution.* Referring to Fig. 3, Chapter 13, a piping and pick-up factor for a net load of 1500 sq ft is found to be 43 per cent or the gross output is equivalent to $1500 \times 1.43 = 2145$ sq ft hot water radiation.

Using the charts in Figs. 1, 2 and 3 project vertically from the gross output value on the proper horizontal scale to the intersection of the 70 per cent efficiency line. From the intersection of this line proceed horizontally to the proper vertical scale where a direct value of the required fuel burning rate is given. These values are rates of burning while firing device is in operation and are not indicative of hourly fuel consumption.

By use of the respective charts the firing rates for the various fuels will be found to be: coal 36.8 lb per hour, oil 3.2 gal per hour, and gas 460 cu ft per hour.

[1]Standard Code Regulating the Installation of Gravity Warm Air Heating Systems in Residences (9th edition), and the Technical Code for the Design and Installation of Mechanical Warm Air Heating Systems, may be obtained from the *National Warm Air Heating and Air Conditioning Association*, 50 W. Broad St., Columbus, Ohio.





## DEGREE-DAY METHOD

This method is based on consumption data which have been taken from buildings in operation, and the results computed on a degree-day basis. While this method may not be as theoretically correct as the Calculated Heat Loss Method, it is of more value for practical use.

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 45.

Recently the *National District Heating Association* studied the metered steam consumption of 163 buildings[3] in 22 different cities and published data substantiating the fact that the 65 F base originally chosen by the gas industry is approximately correct. (See Table 2).

If the degree-days occurring each day are totaled for a reasonably long period, the fuel consumption during that period as compared with another period will be in direct proportion to the number of degree-days in the two periods. Consequently, for a given installation, the fuel consumption can be calculated in terms of fuel used per degree-day for any sufficiently long period and compared with similar ratios for other periods to determine the relative operating efficiencies with the outside temperature variable eliminated.

[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.