For round flues, $\frac{p}{a^3} = \frac{6.48}{d^6}$ (d = diameter in inches)

For square flues, $\frac{p}{a^3} = \frac{4}{s^6}$ (s = side of flue in inches)

In Formula 1, the quantity $\frac{NW^2p}{a^3}$ expresses the proportion of the total draft used to produce velocity and to overcome friction due to flow of gases in the stack itself.

Since the area of the flue to be selected is largely dependent on the factor of friction and since also friction is dependent on height (to be determined), it is apparent that Formula 2, which neglects the factor of height, is especially convenient.

$$\frac{NW^2p}{a^3} = \frac{b}{100} \qquad (2)$$

In Formula 2, b = per cent of total draft used for velocity and friction in the stack itself. Thus, if the total weight of gases to be carried per hour is known and a fair allowance for the stack loss is assumed, the area of the flue may be established from the charts (Figs. 2 and 3); or by assuming mean stack temperatures, the factor N may be selected from Table 2, and the area of the flue established by means of Formula 2.

Factor d_a in Formula 1 which represents the available draft at smoke pipe inlet must be established by consideration of the type or style and construction of the boiler to be installed and is made up of items (1), (2), (3) and (4) enumerated under *Draft*.

Whatever the type of boiler or the purpose for which it is to be used, the conditions surrounding its installation must be considered and the available draft necessary for proper operation established before any attempt can be made toward the selection of a chimney. The draft required for any given size and type of boiler should be obtained from the manufacturer and added to the calculated draft for breechings and turns, to determine the available draft desired.

Many heating boilers are installed in old buildings and must be selected for the existing conditions, frequently without the possibility of changing the flue. In this event the available draft under the existing conditions must be established and the boiler selected to give satisfactory results for these conditions. By the use of the charts (Figs. 2 and 3) or Formula 1, the available draft for a given area and height of flue may be determined when the weight of gas flowing is known and the mean stack temperatures assumed.

The mean stack temperatures referred to in this chapter are arithmetical averages between initial and final temperatures. The mean temperatures used for the charts (Figs. 2 and 3) conform to those found in practice and vary from 250 to 500 F, depending on the size of the flue. The mean temperature in the stack is dependent on the ratio of the perimeter to the area of the stack, the height of the stack, the temperature of the air surrounding the stack, the temperature of gases entering the stack and the weight of gas flowing per unit of time, and therefore published formulae and tables designed for use with high pres-

sure boilers are not entirely satisfactory for use with heating boilers. For example, chimneys for high pressure boilers usually are independent stacks of large area with the greatest load (one hundred per cent over load or more) when the outside temperature is 80 F or higher. The temperature drop in the stack under these conditions is not great and most tables and formulae for chimney design assume the temperature of flue gases to be the same as the entering gases. This, of course, is a fallacy, but does not lead to serious error in view of other allowances generally made.

Chimneys for heating boilers are rarely independent of the building walls and often are in the center of the building. A temperature of 40 F has been used in Figs. 2 and 3 on the assumption that when the outside temperature is zero, a chimney in an outside wall has an average temperature surrounding the stack of 40 F. For other temperatures, Formula 1 and Tables 1 and 2 may be used.

Excess Air

In laying out the charts (Figs. 2 and 3) the excess air for combustion has been assumed approximately as follows: coal, 100 per cent; oil, 50 per cent; gas (both manufactured and natural) 50 per cent. These percentages seem to give satisfactory results for chimney design purposes although an excess of about 50 per cent over the theoretical amount is considered good practice for solid fuels.

Friction

Since most flue surfaces are covered with soot, the frictional surface is practically the same whether the flue is lined or unlined, or brick or steel and in these formulae the coefficient has been taken as 0.016. The factors 0.000004 in Table 2 and N in Formula 2 and Table 2 are directly proportional to this coefficient. Since the weight of gases at higher altitudes is less than at sea-level, the velocity must be increased if equal weights of gas are necessary and provision must therefore be made for the increase in resistance resulting from the increase in velocity. In the formula for N on which Table 2 is based, it will be noted that the proportion of the total draft to overcome resistance in the stack itself varies inversely as the square of the barometric pressure (expressed in inches of mercury) when other conditions such as temperature, weight of gases flowing per unit time and area of stack remain unchanged.

Altitude

In constructing Tables 1 and 2 and Figs. 2 and 3, sea-level pressure (29.92 in. of mercury) has been used. For any other altitude, M in Table 1 would vary inversely as the barometric pressure and N in Table 2 would vary inversely as the square of the barometric pressure. Correction factors for altitude are given in Table 3.

It is possible with Formula 1 to work out a set of tables applicable to any altitude, but it is sufficiently accurate in most cases to increase both the area and height 2 per cent for each 500 ft above sea-level. In order to avoid impractical heights of chimney stacks due to the altitude, boilers with low draft requirements should be selected. This may be done by means of increased grate surface with the consequent lower rate of combustion or by lesser depth of fuel.