In general, the barometric pressure decreases approximately 0.1 in. of mercury per 100 ft increase in elevation.

2. The *unit weight of a cubic foot* of chimney gases at 0 F and sea level barometric pressure is given by the equation:

$$W_c = 0.131 CO_2 + 0.095\, O_2 + 0.083\, N_2 \qquad (3)$$

In this equation CO_2, O_2 and N_2 represent the percentages of the parts by volume of the carbon dioxide, oxygen and nitrogen content, respectively, of the gas analysis. For ordinary operating conditions, the value of W_c may be assumed at 0.09.

The density effect on the chimney gases due to superheated water vapor resulting from moisture and hydrogen in the fuel, or due to any air infiltrations in the chimney proper are here disregarded. Though water vapor content is not disclosed by Orsat analysis, its presence tends to reduce the actual weight per cubic foot of chimney gases.

3. The *atmospheric temperature* is the actual observed temperature of the outside air at the time the analysis of the operating chimney is made. The mean atmospheric temperature in the temperate zone is approximately 62 F.

4. The *chimney gas temperature* does not vary appreciably from the gas temperature as it leaves the breeching and enters the chimney. For average operating conditions, the chimney gas temperature will vary between 500 F and 650 F except in the case when economizers and recuperators are used, when the temperature will vary between 300 F and 450 F. If a chimney has been properly constructed, properly lined and has no air infiltration due to open joints, the temperature of the gases throughout the chimney will not differ appreciably from the foregoing figures. In most up-to-date heating plants, the temperature may be read from instruments or ascertained from a pyrometer. The analysis of this section is predicated on the assumption of constant gas temperature and no air infiltration throughout the height of the chimney.

5. The *coefficient of friction* between the chimney gases and a sooted surface has been taken by many workers in this field as a constant value of 0.016 for the conditions involved. This value, of course, would be less for a new unlined steel stack than for a brick or brick-lined chimney, but in time the inside surface of all chimneys regardless of the materials of construction becomes covered with a layer of soot, and thus the coefficient of friction has been taken the same for all types of chimneys and in general constant for all conditions of operation. For reasons of simplicity and convenience to the reader, this constant value of 0.016 has been employed in the development of the various special equations and charts shown in this chapter.

However, much to be recommended as an alternate method is the practise of separately determining duct friction factors as a function of the flow conditions, specifically as a function of the Reynolds number and the relative duct roughness. The Reynolds criterion is based on the physical properties of the gas, the duct dimensions, and the gas velocity. The gas velocity for a chimney is usually well above the critical velocity. It is likely that this procedure of using a separately determined variable friction factor for chimney flow will give results that are to be preferred over those based on a set constant.

The Reynolds number, a dimensionless ratio, may be stated as follows:

$$C_r = \frac{DV\rho}{\mu} \qquad (4)$$

where

D = chimney diameter, feet.
V = velocity of hot gas, feet per second.
ρ = mass density of the chimney gas per cubic foot.
μ = viscosity of the gas in pounds-second per square foot taken at the gas temperature.

In another form:

$$C_r = \frac{1.27\,W}{D\mu g} = \frac{0.0396\,W}{D\mu} \qquad (5)$$

where

W = weight of gas passed per second.
g = acceleration of gravity.

The value of μ for chimney gases is usually taken as that of air or nitrogen, and for the variation of μ with temperature, the Sutherland equation may be employed as follows, giving μ in pounds-second per square foot:

$$\mu = \mu_0 \left[\frac{273 + C}{T_c + C}\right] \left[\frac{T_c}{273}\right]^{1.5}$$

where

T_c = chimney gas temperature, degrees Centigrade.
μ_0 = gas viscosity at *0 C*.
C = constant for specific gas.

Using International Critical Table values, for air $\mu_0 = 35.6 \times 10^{-8}$; $C = 124$; for nitrogen $\mu_0 = 34.5 \times 10^{-8}$; and $C = 110$.

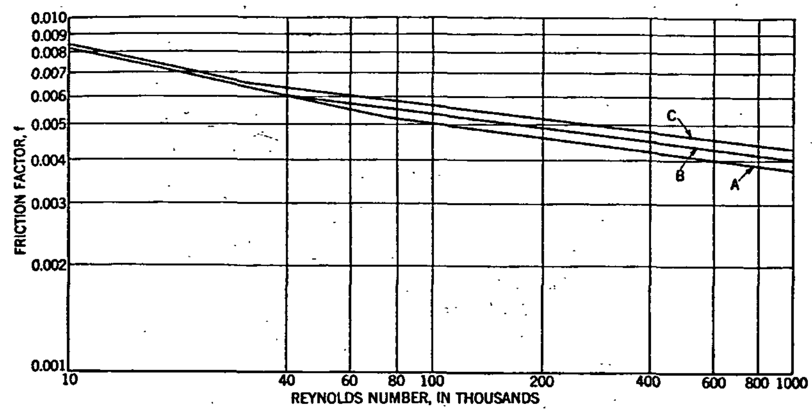

FIG. 5. VARIATION OF FRICTION FACTOR *f* WITH REYNOLDS NUMBER

Values for the viscosity of air and of nitrogen (the principal component of chimney gases) for the different temperatures follow, in which the values given in pounds-second per square foot are to be multiplied by 10^{-8}:

Temp. F	300	400	500	600	700	800
Air	49.7	54.5	58.5	62.5	66.7	70.5
Nitrogen	47.7	52.2	56.0	59.8	63.5	67.0

Example 2. To determine the Reynolds number C_r for a flow of 118 lb gas per second up a 12 ft diameter chimney at a temperature of 500 F. The gas may be assumed to have the same viscosity as nitrogen at 500 F. Using Equation 5:

$$C_r = 0.0396\frac{W}{D\mu} = \frac{0.0396 \times 118}{12 \times 56.0 \times 10^{-8}} = 698{,}000$$

The variation of the friction factor f with the Reynolds number is shown in Fig. 5[1]. Three curves are shown: A, B, and C, where the choice of the friction factor curve depends on the relative surface roughness, and this for usual chimney construction may

[1]See also Flow of Fluids in Closed Circuits, by R. J. S. Pigott (*Mechanical Engineering*, August, 1933).