

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* decreases from the breeching connection to the top of the stack. This drop in temperature depends upon the material and construction of the stack, its tightness or freedom from leaks, its area, its height, and the velocity of the gases through it. The same chimney will suffer different temperature losses depending upon the capacity under which it is working and the variable atmospheric conditions. No general equation covering all these variables has been suggested, but from observations on chimneys varying in diameter from 3 to 16 ft and in height from 100 to 250 ft Equation 5 was deduced¹:

$$T_c = \frac{3.13 T_1 \left[\left(\frac{H_b}{3} \right)^{0.98} - 1 \right]}{H_b - 3} \quad (5)$$

where

T_1 = absolute temperature at the center of the connection from the breeching, degrees Fahrenheit.

H_b = the height of the stack above center line connection to breeching, feet.

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.

In important chimney design, especially when the construction or the materials are unusual, it is recommended that use be made of Reynolds' number² in determining the friction factor, f .

To illustrate the use of Equation 2, the following problem is solved by its use.

Example 1. Determine the available draft of a natural draft chimney 200 ft in height and 10 ft in diameter operating under the following conditions: atmospheric temperature, 62 F; chimney gas temperature, 500 F; sea level atmospheric pressure, $B_0 = 29.92$ in. Hg; atmospheric and chimney gas density, 0.0863 and 0.09, respectively; coefficient of friction, 0.016; length of friction duct, 200 ft. The chimney discharges 100 lb of gases per second.

Substituting these values in Equation 2 and reducing:

$$D_a = 2.96 \times 200 \times 29.92 \times \left(\frac{0.0863}{522} - \frac{0.09}{960} \right) - \frac{0.00126 \times 100^2 \times 960 \times 0.016 \times 200}{10^4 \times 29.92 \times 0.09} \\ = 1.27 - 0.14 = 1.13 \text{ in.}$$

Fig. 1 shows the variation in the available draft of a typical 200 ft by 10 ft chimney operating under the general conditions noted in Example 1. When the chimney is under static conditions and no gases are flowing, the available draft is equal to 1.27 in. of water, the theoretical intensity. As the amount of gases flowing increases, the available draft decreases until it becomes zero at a gas flow of 297 lb per second, at which point the draft loss due to friction is equal to the theoretical intensity. The point of maximum draft and zero capacity is called shut-off draft, or point of

¹Notes on Power Plant Design, by E. F. Miller and James Holt (Massachusetts Institute of Technology, 1930).

²A.S.H.V.E. RESEARCH REPORT No. 1105—Frictional Resistance to the Flow of Air in Straight Ducts, by F. C. Houghten, J. B. Schmieler, J. A. Zalovcik and N. Ivanovic (A.S.H.V.E. TRANSACTIONS, Vol. 45, 1939, p. 35) and for more complete discussion see Flow of Fluids in Closed Conduits, by R. J. S. Pigott (Mechanical Engineering, August, 1933).

impending delivery, and corresponds to the point of shut-off head of a centrifugal pump. The point of zero draft and maximum capacity is called the wide open point and corresponds to the wide open point of a centrifugal pump. A set of operating characteristics may be developed for any size chimney operating under any set of conditions by substituting the proper values in Equation 2 and then plotting the results in the manner shown in Fig. 1.

Fig. 2 is a typical chimney performance chart giving the available draft for various gas flow rates and sizes of chimney. This chart is based on an atmospheric temperature of 62 F, a chimney gas temperature of 500 F, a unit chimney gas weight of 0.09 lb per cubic foot, sea level atmospheric pressure, a coefficient of friction of 0.016, and a friction duct length equal to the height of the chimney above the grate level. These curves may be

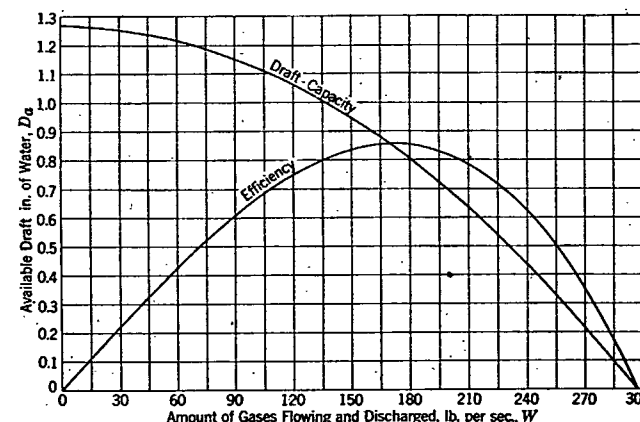


FIG. 1. TYPICAL SET OF OPERATING CHARACTERISTICS OF A NATURAL DRAFT CHIMNEY

used for general operating conditions. For specific conditions, a new chart may be prepared from Equation 2 or 3.

DETERMINING CHIMNEY SIZES

If the required performance for a proposed chimney is known and if a chimney-gas velocity is assumed, Equation 2 can be transposed to yield the necessary height and an equation can be developed for the required diameter. These operations result in the following equations:

$$H = \frac{D_r}{2.96 B_0 \left(\frac{W_0}{T_0} - \frac{W_c}{T_c} \right) - \frac{0.184 f W_c B_0 V^2}{T_c D}} \quad (6)$$

The weight of gas per second, $W = 12.075 \frac{D^3 V B_0 W_c}{T_c}$ from which

$$D = 0.288 \sqrt{\frac{W T_c}{B_0 W_c V}} \quad (7)$$

where

H = required height of chimney above grate, feet.

D = required minimum diameter of chimney, feet.