where

D_a = available draft, inches of water.
H = height of chimney above grate bars, feet.
B_o = barometric pressure corresponding to altitude, inches of mercury.
W_o = unit weight of a cubic foot of air at 0 deg Fahrenheit and sea level atmospheric pressure, pounds per cubic foot.
W_c = unit weight of a cubic foot of chimney gases at 0 deg Fahrenheit and sea level atmospheric pressure, pounds per cubic foot.
T_o = absolute temperature of atmosphere, degrees Fahrenheit.
T_c = absolute temperature of chimney gases, degrees Fahrenheit.
W = amount of gases generated in the combustion chamber of the boiler and passing through the chimney, pounds per second.
f = coefficient of friction.
L = length of friction duct of the chimney, feet.
D = minimum diameter of chimney, feet.

The first term of the right hand expression of Equation 1 represents the theoretical draft intensity and the second term, the loss due to friction.

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_o = 29.92 in. of mercury; atmospheric and chimney gas density, 0.0863 and 0.09, respectively; coefficient of friction, 0.016; length of friction duct, 200 ft; and discharging 100 lb of gases per second.

Substituting these values in Equation 1 and reducing:

$$D_a = 2.96 \times 200 \times 29.92 \times \left(\frac{0.0863}{522} - \frac{0.09}{960}\right) - \frac{0.00126 \times 100^2 \times 960 \times 0.016 \times 200}{10^5 \times 29.92 \times 0.09}$$

$$= 1.27 - 0.14 = 1.13 \text{ in.}$$

Fig. 4 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 intensity 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 draft-capacity curve corresponds to the head-capacity curve of centrifugal pump characteristics and the dynamic-head-capacity curve of a fan. The point of maximum draft and zero capacity is called shut-off draft, or point of 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 1 and then plotting the results in the manner shown in Fig. 4.

The efficiency of a natural draft chimney is the thermodynamical ratio of the energy output to the energy input. The energy output is the total

work done by the chimney in moving the gases and corresponds to the water horsepower of a centrifugal pump, or the total work done by a fan in moving the gases. The energy input is equal to the theoretical amount of power generated by the chimney and corresponds to the power input of the driving unit of a centrifugal pump or a fan. The thermodynamical efficiency is given by the equation:

$$E_t = \frac{K_a W D_a}{A\sqrt{H}} \tag{2}$$

where

K_a = a constant depending upon the temperature of the gases, the atmospheric temperature, the elevation of the plant, and the density and specific heat of the gases. For average operating conditions, K_a = 0.0065.

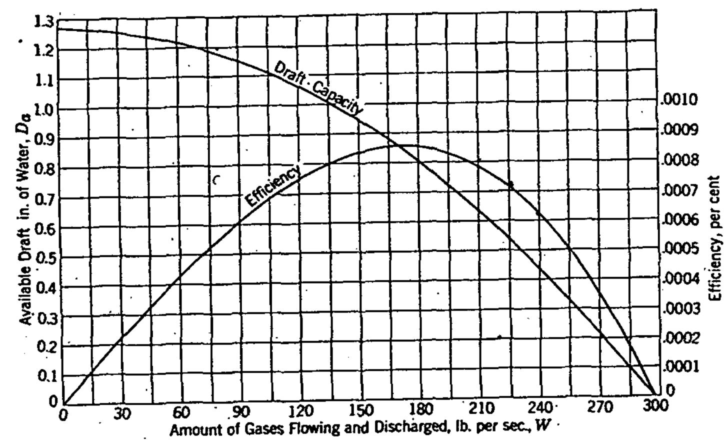

FIG. 4. TYPICAL SET OF OPERATING CHARACTERISTICS OF A NATURAL DRAFT CHIMNEY

Fig. 4 shows the variation in the efficiency of the chimney under consideration for the operating conditions noted. This curve rises from zero at shut-off draft to a maximum for a certain draft and its corresponding capacity and then drops again to zero at the wide open point. The point of maximum efficiency is located by the point on the draft-capacity curve equal to two-thirds of the theoretical draft intensity. In Example 1 the maximum efficiency is at an available draft intensity of ⅔ × 1.27 = 0.85 in. of water and the corresponding capacity of 175 lb per second.

The efficiency curve of a natural draft chimney corresponds to the efficiency curves of a centrifugal pump and a fan and serves the same general use in that it locates the region of most economical operation. In substituting the values for the various factors in Equation 1, care should be exercised that the selections be as near the actual conditions as is practically possible. The following notes will serve as a guide for these selections: