tion, together with the reduced heat losses up the chimney by reason of decreased gas velocity, results in fuel economy, with consequent lower costs of plant operation.

CHARACTERISTICS OF CHIMNEYS

In order to analyze the performance of a natural draft chimney, it may be advantageous to compare its general operating characteristics with those of a centrifugal pump and also of a centrifugally-induced draft fan, there being a similarity among the three. Figs. 2, 3 and 4 show the general operating characteristics of a typical centrifugally-induced draft fan, a typical centrifugal pump, and a typical natural draft chimney, respectively. The draft-capacity curve of the chimney corresponds to

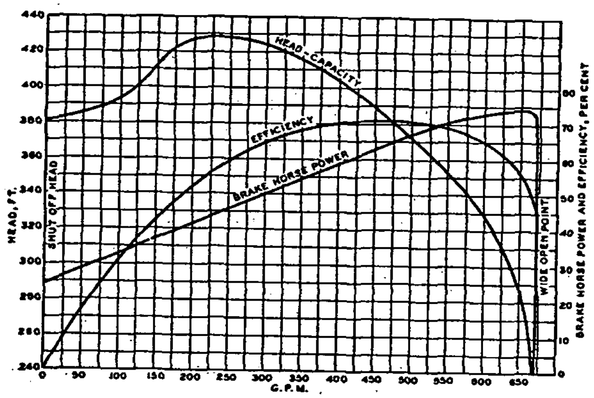

FIG. 3. OPERATING CHARACTERISTICS OF TYPICAL CENTRIFUGAL PUMP

the head-capacity curve of the pump and also to the dynamic-head-capacity curve of the fan.

When the gases in the chimney are stationary, the draft created is termed the *theoretical draft*. When the gases are flowing, the theoretical intensity is diminished by the draft loss due to friction, the difference between the two being termed the total *available draft*.

If pressures at the bases of a column of air and a column of chimney gas, each of height H feet; and d_o and d_c represent the respective densities of the air and the gas in pounds per cubic foot, then the theoretical draft D_t in pounds per square foot is:

$$D_t = d_oH - d_cH$$

Expressing the densities under standard conditions of pressure and temperature, and assuming that the absolute pressure of the gas is the same as that of the air, the theoretical draft becomes:

$$D_t = 15.36\ HB_o\left(\frac{W_o}{T_o} - \frac{W_c}{T_c}\right)$$

Expressed in inches of water this is:

$$D_t = 2.96\ HB_o\left(\frac{W_o}{T_o} - \frac{W_c}{T_c}\right)$$

The friction loss in the chimney may be determined from the Fanning equation:

$$\text{Head lost in feet of fluid} = \frac{fRL}{A} \times \frac{V^2}{2g}$$

in which R is the inside perimeter of the cross-section in feet, A the cross-section area in square feet, and V the velocity of fluid in feet per second.

Substituting for V its value in terms of W and the cross-section area, and expressing the loss of head in inches of water this becomes:

For cylindrical stacks

$$h_L = 0.01936\ \frac{fLW^2}{D^5 d_c}$$

and for a rectangular stack of sides x and y in feet,

$$h_L = 0.00597\ \frac{fLW^2(x + y)}{xy^3\ d_c}$$

Substituting for d_c its value:

$$\frac{460\ B_o\ W_c}{29.92\ T_c}$$

gives for a cylindrical stack,

$$h_L = 0.00126\ \frac{W^2\ T_c fL}{D^5\ B_o\ W_c}$$

and for a rectangular stack,

$$h_L = 0.000388\ \frac{W^2\ T_c fL\ (x + y)}{xy^3\ B_o\ W_c}$$

The available draft then is, for a cylindrical stack:

$$D_a = 2.96HB_o\left(\frac{W_o}{T_o} - \frac{W_c}{T_c}\right) - \frac{0.00126W^2T_cfL}{D^5B_oW_c} \qquad (1)$$

and for a rectangular stack:

$$D_a = 2.96\ HB_o\left(\frac{W_o}{T_o} - \frac{W_c}{T_c}\right) - \frac{0.000388\ W^2\ T_c fL\ (x + y)}{xy^3\ B_o\ W_c} \qquad (2)$$

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 F and sea level atmospheric pressure, pounds per cubic foot.
W_c = unit weight of a cubic foot of chimney gases at 0 F 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 = weight 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.