

Chimneys and Draft Calculations

Natural Draft, Mechanical Draft, Draft Control, Characteristics of Natural Draft Chimneys, Determining Chimney Sizes, General Equation, Domestic Chimneys, Chimneys for Gas Heating, Construction Details

DRAFT, in the older sense, is a current of air and the draft of a furnace or boiler is that air current which flows through the fire-box and furnishes the oxygen for combustion. In engineering, however, the word *draft* has come to mean that pressure difference which causes this air current to flow and the word will be used in this sense in this chapter.

Draft is usually measured in inches of water and it is proper to speak of the draft in the fire-box or in the smoke breeching, etc., meaning the difference in pressure between the gases within and the air without those parts of a system. Draft is called positive when the pressure within such a part is less than that outside.

Draft is classified as natural and mechanical, depending on whether it is produced by a chimney or by a blower, and mechanical draft is further classified as induced or forced; depending on whether the air is drawn through or forced through the combustion chamber.

Chimneys can serve both to create a draft and to dispose of combustion products at a desirable height. For the latter purpose, chimneys, stacks, or, in the case of ships, funnels, are used in conjunction with mechanical-draft systems.

THEORETICAL DRAFT

If the air in one of two equal chimneys is heated while that in the other is not, the air in the heated chimney will be less heavy than that in the other chimney and a manometer or other pressure gage connecting the two at the bottom will indicate a pressure difference, called natural draft. The pressure of the air at the tops of the two chimneys will be equal, so that the pressure difference between them at the bottom will depend only on their height and the difference in density of the air they contain. The density of the air in either chimney is inversely proportional to its absolute temperature, so that the difference in pressure between them at the bottom will be proportional to their height and to the difference between the reciprocals of the absolute temperatures within them.

The pressure at the bottom of an unheated (and uncooled) chimney will be the same as that of the air outside, so that the unheated chimney can be dropped from the foregoing illustration. The manometer reading will be the same if its free connection is left open to the atmosphere.

These considerations in conjunction with those of barometric pressure and the difference in density of flue gases from that of air lead to the following formula:

$$D_t = 2.96 HB_o \left(\frac{W_o}{T_o} - \frac{W_c}{T_c} \right) \quad (1)$$

where

H = height of chimney, feet.

B_o = existing barometric pressure, inches of mercury.

W_o = density of air at 0 F and 1 atmosphere pressure, pounds per cubic foot.

W_c = density of flue gas at 0 F and 1 atmosphere pressure, pounds per cubic foot.

T_o = temperature of air surrounding the chimney, degrees Fahrenheit absolute.
 T_c = average or effective temperature of the gases in the chimney, degrees Fahrenheit absolute.

The quantity D_t , yielded by the formula, is the pressure difference between the gas inside and air outside of the chimney, in inches of water, when no flow occurs in the chimney. The quantity is variously known as the theoretical draft, the static draft or the computed draft. It is very useful in predicting and analyzing chimney performance, but it is seldom if ever attained in an actual chimney on account of the friction incident to gas flow, wind effects, etc.

AVAILABLE DRAFT

The available draft, D_a , for large chimneys and stacks has been estimated with apparent satisfaction in the past by means of formulae which in effect deduct an estimated friction loss from a theoretical draft determined as in Equation 1. The friction loss can be estimated by means of one of the formulae available for ducts, such as the Fanning equation. This procedure results in formulae for the available draft as follows:

For a *cylindrical* stack:

$$D_a = 2.96 HB_o \left(\frac{W_o}{T_o} - \frac{W_c}{T_c} \right) - \frac{0.00126 W^2 T_c f L}{D^5 B_o W_c} \quad (2)$$

and for a *rectangular* stack:

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

where

D_a = available draft, inches, water gage.

H = height of chimney above grate, feet.

B_o = existing barometric pressure, inches of mercury.

W_o = density of air at 0 F, 1 atmosphere pressure.

W_c = density of flue gas at 0 F, 1 atmosphere pressure.

T_o = temperature of atmosphere, degrees Fahrenheit absolute.

T_c = temperature of flue gas, degrees Fahrenheit absolute.

W = flue gas flow rate, pounds per second.

f = coefficient of friction.

L = length of friction duct (= H approximately), feet.

D = minimum diameter of round chimney, feet.

x and y = length and width of cross-section of rectangular chimney, feet.

The following notes are intended to facilitate the use of Equations 2 and 3.

1. The *barometric pressure*, represented by B_o , is the actual pressure at the site of the chimney and not the pressure reduced to sea level datum.

In general, the barometric pressure decreases approximately 0.1 in. Hg 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:

$$W_c = 0.131 CO_2 + 0.095 O_2 + 0.083 N_2 \quad (4)$$

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 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.