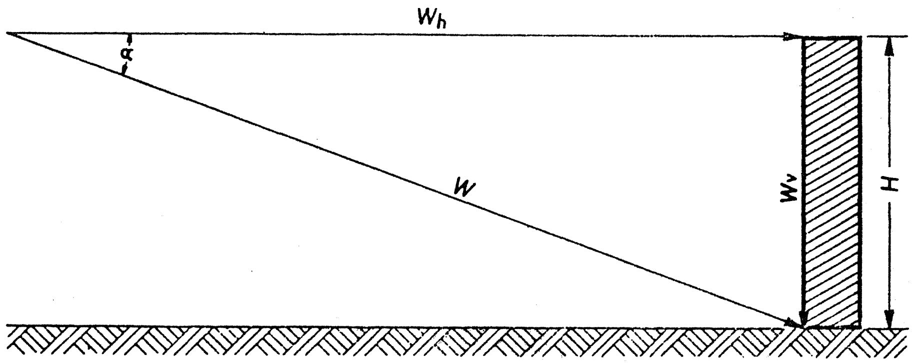
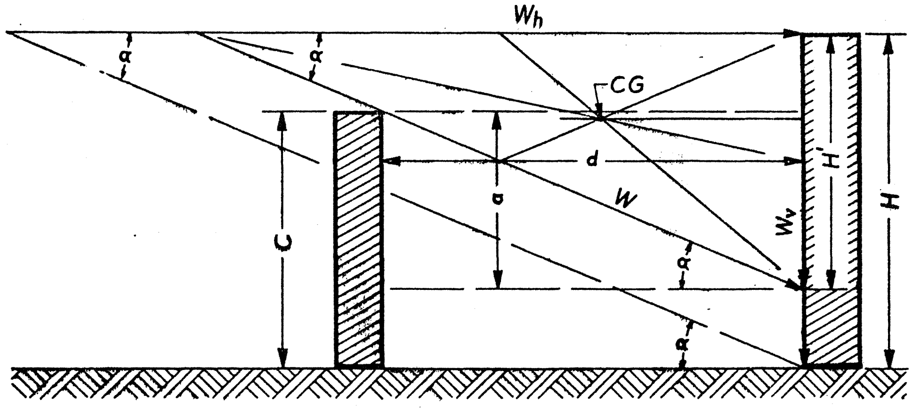


1 RELATIONSHIP of horizontal and vertical components of effect of wind on a building is depicted here, where *H* is building height, *W* is wind direction, α is angle to ground, W_h is wind horizontal component, W_v is wind vertical component



2 EFFECT OF INFILTRATION can be calculated for a given building of height *H* at a distance *d* from nearest building with height *C* by using method suggested here

Here's How to Figure Infiltration Due to Stack Effect

. . . when calculating building heat loads

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HOW MUCH should a heating engineer add to the design load for a building to account for infiltration resulting from stack effect? Here's a new approach to figuring this.

The average angle of wind direction with the ground at any point on the earth's surface will depend on the slope of either the cold or warm front caused by atmospheric conditions. Cold front slopes are normally the more steeply inclined. Warm fronts, on the other hand, more generally approach at a shallow angle with the earth's surface.

Air masses passing over a terrain will conform with the general law of fluid wave motion. The ground and the structures on it will resist the lower portion of the air mass and permit the higher portion to accelerate. This creates a tumbling effect much like ocean waves breaking on a beach. When this occurs the slope of the front is changed more radically downward. To date we have no mathematical correlation for this resistance effect.

Some rules of thumb have come from the old sailing days. It was noted that a sail on the windward side of a vessel would cause a "wind shadow" of three to seven times its vertical section (roughly triangular). It is interesting to note that the wind angles with relation to the earth's surface can vary as little as one-tenth of a degree to as much as 30 degrees.

If we draw a building *H* high, and at the same time draw the wind vector, we can resolve the wind vector to a horizontal component and a vertical component. However, if we were to calculate the centroid of the wind force triangle in relation to the centroid of the vertical plane surface of the building, we can see that the combined centroid of the two figures will be slightly above the center of gravity for the vertical plane surface.

It can be assumed that the horizontal component of the wind force will act on the centroid of the structure. In Fig. 1 the building and wind force triangle are indicated as follows:

H = building height
W = wind direction
α = angle to ground
W_h = wind horizontal component
W_v = wind vertical component.

Chapter 11 of the 1958 ASHAE Guide and Table 2 contained therein give this equation:

$$V_e = B\sqrt{h\ (T_1 - T_o)} \quad [1]$$

Where:

B = derived value
V_e = equivalent wind velocity, mph
h = floor height, ft
T_1 = inside temperature, F
T_o = outside temperature, F.

Converting Equation 1:

$$(\text{mph} \times 5280/60) = 88 \times \text{mph} = \text{velocity (fpm)} = V_1$$
$$88\ V_e = V_1$$

Then

$$V_1 = 88\ V_e\ B\sqrt{h\ (T_1 - T_o)} \quad [2]$$

From Chapter 11, Table 2 of the Guide is derived Equation 3:

$$v_1 = Q/A = K\sqrt{H\ (T_1 - T_o)} \quad [3]$$

Where:

v_1 = stack velocity of air caused by temperature difference.
Q = air flow rate, cfm

At the point within the building where the horizontal wind velocity pressure W_h equals the velocity pressure due to stack effect, we can equate:

$$P_1 = P_w \quad [4]$$

Where:

P_1 = stack velocity pressure, in. water gage
P_w = horizontal wind velocity pressure due to W_h, in. WG.

$$P_1 = (v_1/4005)^2 = [K\ [\sqrt{h\ (T_1 - T_o)}/4005]]^2 \quad [5]$$
$$Q = E \times A \times 88\ V_e \quad [6]$$

Where:

E = effectiveness of openings.

$$Q/A = E \times 88 V_e$$
$$P_w = (88 \times E \times V_e/4005)^2 = [88\ BE\ [\sqrt{h\ (T_1 - T_o)}/4005]]^2 \quad [7]$$

But E varies as W_h:—

$$\cos\alpha = W_h/W$$
$$W_h = W\cos\alpha$$
$$E \approx \cos\alpha$$
$$P_w = (88\cos\alpha\ V_e/4005)^2$$
$$= [88\cos\alpha\ B\ [\sqrt{(T_1 - T_o)\ h/4005)}]]^2 \quad [6_a]$$

Converting Equation 5 equal to Equation 6_a and $H = sh$:—

$$[K\sqrt{s}\sqrt{(T_1 - T_o)\ h}/4005]^2$$
$$= [88\cos\alpha\ B\ [\sqrt{(T - T_o)\ h}/4005]]^2 \quad [6_b]$$
$$K\sqrt{s} = 88\cos\alpha\ B \quad [7]$$

At the point of equal pressure on the building wall, the vertical component W_v will be the main force inducing leakage through that floor opening. Therefore:

$$W_v = W\sin\alpha$$
$$B \approx \sin\alpha$$
$$K\sqrt{s} = 88\cos\alpha\sin\alpha.$$

But $\cos\alpha\sin\alpha$ for small angles of $\alpha \approx \tan\alpha$ and:

$$K \approx (88\tan\alpha)/(\sqrt{s}) \quad [8]$$

In Chapter 11 of the 1958 Guide we are told that if all vertical openings are sealed and the floor and ceiling are tight, "no allowance need be made for chimney effect." Since this is not practical for the average building, some approach for approximating the neutral point between stack effect and wind must be made.

Equation 8 then gives the approximate value of K, *where*:

s = number of floors in building
K = derived constant at point of equal pressures.

It is possible to provide *sufficient air pressure* to counteract the infiltration of the building below the neutral point, and exfiltration from the building above the neutral point. It is also possible to determine the vertical zoning of a structure by this method, and locate the neutral points for each zone and determine the necessary air pressures to counteract the external wind force involved.

The problem is complicated because most structures are grouped in an area and vary in height. Consider the following case:

Refer to Fig. 2. Assume all floor heights of the buildings to be approximately the same.

In an isolated case of two buildings:

$$W_v = H'$$
$$H = H' + (c - a)$$

and

$$a/d = \tan\alpha$$

or

$$a = d\tan\alpha$$

Where:

d = distance to highest leeward building, ft.

Since H' and C will vary with the number of stories, then:

$$C = h \times s''$$
$$H = H' + (C - d\tan\alpha)$$

or

$$s = s' + (s'' - d\tan\alpha)$$

and

$$s' = s - s'' + d\tan\alpha \quad [9]$$

Where:

s' = number of floors of taller building exposed to W_h
s = total floors in taller building
s'' = total floors in smaller building to leeward
d = distance apart, ft.

This value of s' should be substituted in Equation 9:

$$K\sqrt{s'} = K\sqrt{s - s'' + d\tan\alpha} \quad [10]$$

and

$$K = 88\tan\alpha/\sqrt{s - s'' + d\tan\alpha} \text{ at equal pressures} \quad [11]$$

The value of α, or average "frontal slope" of prevailing wind for the period desired, can be obtained from weather bureau data. The average would be about 5 deg in summer, 9 deg in spring and fall, and 14 deg in winter.

Equation 11 will be found useful for most all cases. The value of K is then substituted in Equation 8 and the floor location above grade for equal pressure is determined.

Substitute the value of K from Equation 9 in Equation 5 and substitute the value of s for each floor. Then, a series of pressures will be obtained. The larger values of K (above equal pressures) indicate infiltration and the lesser values of K (below normal pressures) show exfiltration. ⌗