

The ventilating results obtained will vary, from time to time, due to variation in the velocity and direction of the wind, and the temperature difference. The arrangement, location, and control of the ventilating openings should be such that the two forces act cooperatively rather than in opposition.

WIND FORCES

In considering the use of natural wind forces for producing ventilation, account must be taken of: (1) average wind velocity; (2) prevailing wind direction; (3) seasonal and daily variations in velocity and direction; and (4) local wind interference by nearby buildings, hills or other obstructions of similar nature.

Values are given in Table 3, Chapter 13 for the average wind velocities for the months June to September in various localities throughout the United States, while Table 1, Chapter 12, lists similar values for the winter. In almost all localities, the summer wind velocities are lower than those in the winter, and in about two-thirds of the localities the prevailing direction is different during the summer and winter. While the tables give no average velocities below 5 mph, there will be times when the velocity is lower, even in localities where the seasonal average is considerably above 5 mph. There are relatively few places where the velocity falls below one-half of the average for many hours per month. Consequently, if the natural ventilating system is designed for wind velocities of one-half of the average seasonal velocity, it should prove satisfactory in almost every case.

Equation 3 may be used for calculating the quantity of air forced through ventilation openings by the wind, or for determining the proper size of such openings to produce given results:

$$Q = EAV \quad (3)$$

where

- Q = air flow, cubic feet per minute.
 A = free area of inlet openings, square feet.
 V = wind velocity, feet per minute, = miles per hour $\times 88$.
 E = effectiveness of openings. (E should be taken at 0.50 to 0.60 for perpendicular winds, and 0.25 to 0.35 for diagonal winds.)^a

The precision of results obtained by the use of Equation 3, depends upon the placing of the openings, as the formula assumes that ventilating openings have a flow coefficient slightly greater than that of a square-edged orifice. If the openings are not advantageously placed with respect to the wind, the flow per unit area of the openings will be less and, if unusually well placed, the flow will be slightly more than that given by the formula. Inlets should be placed to face directly into the prevailing wind, while outlets should be placed in one of the five places listed:

1. On the side of the building directly opposite the direction of the prevailing wind.
2. On the roof in the low pressure area caused by the jump of the wind (see Fig. 2).
3. On the sides adjacent to the windward face where low pressure areas occur.
4. In a monitor on the side opposite from the wind.
5. In roof ventilators or stacks.

TEMPERATURE DIFFERENCE FORCES^a

The stack effect produced within a building, when the outdoor temperature is lower than the indoor temperature, is due to the difference in weight

of the warm column of air within the building and cooler air outside. The flow due to stack effect is proportional to the square root of the draft head, or approximately

$$Q = 9.4A \sqrt{h(t_i - t_o)} \quad (4)$$

where

- Q = air flow, cubic feet per minute.
 A = free area of inlets or outlets (assumed equal), square feet.
 h = height from inlets to outlets, feet.
 t_i = average temperature of indoor air in height h , Fahrenheit.
 t_o = temperature of outdoor air, Fahrenheit.
 9.4 = constant of proportionality, including a value of 65 percent for effectiveness of openings. This should be reduced to 50 percent (constant = 7.2) if conditions are not favorable.

HEAT REMOVAL

In problems of heat removal, knowing the amount of heat to be removed and having selected a desirable temperature difference, the amount of air to be passed through the building per minute, to maintain this temperature difference, can be determined by means of Equation 5.

$$Q = \frac{H}{C_p \times \rho \times 60(t_i - t_o)} = \frac{H}{1.08(t_i - t_o)} \quad (5)$$

where

- Q = air removed, cubic feet per minute.
 H = heat removed, Btu per hour.
 C_p = specific heat of air at constant pressure, 0.24.
 ρ = density of standard air, 0.075 pounds per cubic foot.
 $t_i - t_o$ = indoor-outdoor temperature differences, Fahrenheit.

EFFECT OF UNEQUAL OPENINGS

The largest flow per unit area of openings is obtained when inlets and outlets are equal, and the preceding equations are based on this condition. Increasing outlets over inlets, or vice-versa, will increase the air flow, but not in proportion to the added area. When solving problems having an unequal distribution of openings, use the smaller area, either inlet or outlet, in the equations, and add the increase as determined from Fig. 3.

COMBINED FORCES OF WIND AND TEMPERATURE

Equations have already been given for determining the air flow due to temperature difference and wind. It must be remembered that when both forces are acting together, even without interference, the resulting air flow is not equal to the sum of the two estimated quantities. The flow through any opening is proportional to the square root of the sum of the heads acting on that opening.

When the two heads are about equal in value, and the ventilating openings are operated so as to coordinate them, the total air flow through the building is about 10 percent greater than that produced by either head acting independently under conditions ideal to it. This percentage decreases rapidly as one head increases over the other. The effect of the larger head will predominate.

The wind velocity and direction, the outdoor temperature, or the indoor