

where  $V$  = velocity in feet per minute through an opening, and  $p$  is the pressure difference, in inches of water, existing at that opening from any causes or combination of causes.

With  $V$  known, the flow,  $Q$ , at the opening can then be easily computed by the familiar relation.

$$Q = AVC \quad (4)$$

where  $Q$  is the flow in cubic feet per minute;  $A$  is the area in square feet, and  $C$  is a coefficient.

For openings such as result from swinging or sliding windows and doors, where the aperture is essentially an orifice, the value of  $C$  will be about 0.60.

It would be comparatively easy to calculate flow through an opening, if the pressure difference could be determined. However, so many factors participate in the general action that it is very difficult to evaluate a pressure difference arising from a given wind velocity and temperature. The difficulty is further augmented by the fact that the pressure difference is likely to have a different value for every different opening or group of openings of a building.

Although it is almost out of the question to attempt to predetermine accurately the pressure difference from fundamental data of wind velocity, wind direction, temperature difference, building dimensions and disposition of openings, in most cases merely a general knowledge of how the forces of wind and temperature difference act, what their maximum magnitudes are, and how they are disposed in and about a building, will be helpful in planning ventilation. On this basis, the following simple rules are suggested:

1. In an industrial building where furnaces, that give off heat and fumes, are to be installed, it is better to locate them in the end of the building exposed to the prevailing wind. The strong suction effect of the wind at the roof near the windward end will then cooperate with temperature difference, to provide for the most active and satisfactory removal of the heat and gas laden air.
2. In case it is impossible to locate furnaces in the windward end, that part of the building in which they are to be located should be built higher than the rest, so that the wind, in splashing therefrom will create a suction. The additional height also increases the effect of temperature difference to cooperate with the wind.
3. In the use of monitors, windows on the windward side should usually be kept closed, since, if they are open, the inflow tendency of the wind counteracts the outflow tendency of temperature difference. Openings on the leeward side of the monitor result in cooperation of wind and temperature difference.
4. In order that the force of temperature difference may operate to maximum advantage, the vertical distance between inlet and outlet openings should be as great as possible. Openings in the vicinity of the neutral zone are less effective for ventilation.
5. In order that temperature difference may produce a motive force, there must be vertical distance between openings. That is, if there are a number of openings available in a building, but all are at the same level, there will be no motive head produced by temperature difference, no matter how great that difference might be.
6. In the design of window ventilated buildings, where the direction of the wind is quite constant and dependable, the orientation of the building together with amount and grouping of ventilation opening can be readily arranged to take full advantage of the force of the wind. On the other hand, where the direction of the wind is quite variable, it may be stated as a general principle that windows should be arranged in sidewalls and monitors so that there will be approximately equal area on all sides. Thus, no matter what the wind's direction, there will always be some openings directly

exposed to the pressure force of the wind, and others opposed to a suction force, and effective movement through the building will be assured.

#### Control of Natural Ventilation

Control of natural ventilation depends upon hand regulation, which may be applied in two ways: *First*, by the selection of appropriate localities about the building at which to make openings, with regard to direction of the wind, and *Second*, by regulation of the amount of opening, which is accomplished by window operative devices, dampers, or louvers. Control may be effected by the regulation of either inlet or outlet openings, or both and for satisfactory results needs careful study and close attention.

#### Natural Ventilation Openings

The openings employed in natural ventilation are:

1. Windows (or doors) representing apertures in walls and roofs.
2. Openings in the roof which may have cowls for induced effect due to wind.

*Windows* have the advantage of transmitting light, as well as providing ventilating area when open. Their movable parts are arranged to open in various ways; they may open by sliding as in the ordinary double-hung, wood window; by tilting on horizontal pivots at or near the center; or by swinging on pivots at top or bottom. Whatever the form and type of window used the thing of essential importance in ventilation is the amount of clear area that can be made available. The motive head to produce flow through windows is almost entirely dependent upon the distribution of those motive forces in and about a building, as discussed under wind and temperature difference. A pivoted window, projecting out from the plane of the wall is bound to impose some obstructive influence upon such air currents as exist in that particular vicinity, and may result in the production of some localized pressure or suction that will influence flow there, and to that degree, one type of window might give more or less active ventilation than another. But, speaking generally, the motive head causing flow through a window is determined by the forces of wind and temperature difference existing there, and not by the kind of window, except in so far as the kind of window establishes the area of opening.

Windows may be arranged for individual operation, or they may be grouped in long runs, as in factory buildings. Those used in office buildings may have deflecting devices at the sills for avoiding direct draft upon occupants, or a bottom pivoted ventilator, arranged to swing in at the top, may serve the same purpose.

*Roof outlets* concern mechanical as well as natural ventilating systems. A roof ventilator of the unit type consists of a structure built up around a roof opening in such a way as to cause the wind to induce a suction in the vicinity of the opening, and so create an outflow. Since roof ventilators are intended for installation on roofs of buildings, and function as outflow openings only, they constitute but a part of a ventilating system, and attention must be given to the provision of openings for inflow. It is evident that such ventilators could not function even in the strongest wind, and with the maximum temperature difference, without inlet-open-