distance between inlet openings below and outlet openings above; and D is the temperature difference.

The total force or head is consumed in forcing the air in at inlet openings, through the building, and out at the outlet openings. The force required to move the air through the building is usually negligible, so that the total head may be considered as being consumed at inlet and outlet openings. The part of the total head consumed in forcing the air to flow through the lower or inlet opening will be manifested as an excess of outside pressure over inside pressure at that level; while at the upper or outlet opening, the part of the total head consumed in forcing the air out will be manifested as a pressure inside, greater than outside. Thus the lower part of the building inside will be in a state of partial vacuum with respect to the outside, while the upper part will be in a state of pressure. At some point between the levels of the two openings, the pressure state is neutral, and no flow will take place through an opening at that level. This level is called the *neutral zone*.[2]

Relation between Head and Flow

The relation between head or pressure difference on the two sides of an opening, and the velocity that will be created thereby, is given approximately by equation (3).

$$V = 4{,}000\sqrt{p} \tag{3}$$

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.

$$Q = AVC \tag{4}$$

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.

NATURAL VENTILATION SYSTEMS

The success of natural systems of ventilation depends on one or more of the following factors:

1. The availability of the natural force employed, whether it be the wind or temperature difference, or both.

[2] See *The Neutral Zone in Ventilation*, by J. E. Emswiler, A.S.H.V.E. TRANSACTIONS, Vol. 32, 1926; also p. 78, Chapter 4.

2. The size and location of openings and of ducts, flues, dampers, louvres and other appurtenances.

3. The extent of the regulation of the operative devices, which must function almost entirely by means of hand control.

Gravity Systems

Gravity systems obtain the necessary pressure difference by using chimneys which are called vent flues, and which become more and more effective as the difference between the outside and inside temperatures increases. As long as a temperature difference of not less than 40 deg. between indoors and outdoors exists, these systems can be depended upon for a definite result. With slight temperature differences, the effectiveness of gravity systems decreases rapidly.

Gravity ventilating systems usually must operate, except when the rooms are on the windward side of the building, at somewhat lower atmospheric pressure than that out-of-doors. This is due to the necessity for pressure-difference to cause air to enter the rooms on the leeward side.

For the first hour or so of school on a cold morning, a well-designed gravity ventilating system will function well. After that period and in comparatively mild weather, gravity ventilating systems cease to function since heat must be shut off from the radiator and the temperature difference which causes air movement must, without heat, decrease rapidly.

Gravity ventilating systems are not well adapted to the installation of humidifiers and air cleaners, and their control and upkeep with such systems is difficult.

Studies of buildings which operate with gravity ventilating systems indicate that the windward rooms usually may, with care, be provided with satisfactory air movement and temperature control, but that during this time the leeward rooms get too warm and usually cannot be made to receive any air supply except that which comes through the windward rooms and the corridors.

Direct-Indirect Gravity Ventilating Systems

Direct-indirect gravity ventilating systems have small openings through the outside walls below windows, with encasement of the superimposed radiator sections and are sometimes used in school building gravity ventilation. This system is very difficult to control, and becomes less and less effective as the temperature difference between indoors and outdoors decreases. The windward rooms may receive more air supply than can be warmed, while simultaneously, the leeward rooms are losing heated air due to reverse air currents through the direct-indirect heaters, due to the low pressure zone which always occurs in the lee of any obstruction during a high wind.

Indirect Systems of Gravity Ventilation

Indirect systems of gravity ventilation with convectors in the basement may operate satisfactorily so long as their air supply comes from windward and the temperature conditions inside and out permit the convectors or radiators to be heated. As soon as the heat is shut off from these