(or gains in the case of a cooling system), and the effect on air distribution of cold wall and glass surfaces, radiators, lights, and the bodily heat of the occupants.

Uniform Distribution

Where accurate humidity control is required, uniform temperature conditions are very important, because a change in temperature means a change in relative humidity even though the absolute humidity (grains of moisture per pound of air) is constant. For this reason the air must be distributed uniformly, not with respect to floor space, but with respect to the amount of heat to be absorbed in the various portions of the room. The designer of air conditioning systems, particularly for industrial plants, must therefore have fairly exact information as to the distribution and source of heat within the room, or else have means of controlling the temperature or quantity of air supplied to the different sections independently.

In industrial plants the higher duct velocities which are ordinarily employed assist in providing general air movement and uniformity of distribution. The high outlet velocity sets in motion a considerably larger amount of room air. The effectiveness of this action depends on the entering velocity, and where drying processes are involved, high entering velocities are often used for setting in motion large volumes of air and obtaining uniform drying.

Grilles and Registers

The plain lattice grille of cast-iron or pressed steel with from 40 to 60 per cent net clear area is the type generally used in ventilation work, but the recommendations regarding velocities apply also to ornate patterns. Registers are not as generally used in ventilation and air conditioning work as grilles. It has proved more satisfactory and economical to install a damper in the duct leading to the grille. In some instances the deflection caused by the shutters in a register seriously affects distribution.

Where the occupants of the room are close to the registers or grilles, the size should be such that the velocity through them will be from 200 to 400 fpm, depending on the location and kind of installation, as already stated. However, low air velocities induce stratification and where the ceiling height will permit, velocities as high as 800 fpm may be used. The velocity through floor registers should vary between 125 and 175 fpm. Much will depend on the location of grille, the direction of the air flow and the distance it should carry.

MEASUREMENT OF AIR FLOW

The quantity, velocity and pressure of air discharged by a fan or flowing through a duct or grille may be determined by various methods. Those in common use are by Pitot tube, Kata thermometer and anemometer readings, the latter being suitable for low air velocities and being commonly used for measurements at points where the air is not confined in a duct. The use of calibrated nozzles, orifice plates, or Venturi meters are recognized methods, which, however, have little application in connection with ventilation practice.

Pitot Tubes

This usually consists of two tubes, one within the other, which when properly held in the air stream will register the total or impact pressure and the static pressure, respectively. If these tubes are connected to opposite sides of a water column the recorded pressure will be the differential or velocity head. Volume measurements may thus be made in a duct of known area. Pitot tube measurements are preferably used for air velocities exceeding 20 fps. Volumetric determinations from Pitot tube readings must take into account the barometric pressure, temperature and humidity. These factors determine the weight or density of the air.

In general no accurate velocity pressure readings can be taken when the flow of air in ducts is turbulent. To insure accuracy a straight section of duct from 5 to 10 times its own diameter is desirable in order to straighten out the air currents. If it is necessary to take Pitot tube readings in shorter sections of straight duct, the results must be considered subject to some doubt and checked accordingly. For accurate work it is necessary to make a traverse of the duct, dividing its cross section into a number of imaginary equal areas and taking a reading in the center of each, the average of the velocities corresponding to these pressures giving the true velocity in the duct.

Anemometers

These instruments are quite delicate, and when accuracy is required should be frequently calibrated. The ordinary method of taking air velocities over an area is to make a traverse as described in connection with the Pitot tube, the instrument being moved from one section or area to the next at regular intervals so that the total reading is the average velocity of flow for the total elapsed time. The anemometer as usually calibrated reads directly in linear feet. This reading must be divided by the elapsed time in minutes to obtain the velocity in feet per minute.

The following procedure for obtaining anemometer readings is based on research conducted at *Armour Institute of Technology* in cooperation with the A.S.H.V.E. Research Laboratory[b].

Supply Grilles. The surface of the grille should be marked off into a number of equal areas approximately 6 in. square. A 4-in. anemometer should be used and should be held at the center of each section in contact with the grille (or as close as possible), for a period of time sufficient to insure an average reading. In the case of supply grilles, the instrument should always be held with the dial facing the operator. The average of the corrected readings should then be used in the following formula to obtain the flow in cubic feet per minute:

$$cfm = CV\frac{A + a}{2} \text{ or } \frac{CVA\,(1 + p)}{2} \qquad (7)$$

where

V = average of corrected anemometer readings in feet per minute.
A = gross area of grille, square feet.
a = net free area of grille, square feet.

[b]Measurement of Flow of Air through Registers and Grilles, by L. E. Davies (*Heating, Piping and Air Conditioning*, January, 1930, and April, 1931).