meter is to be permanently located in the duct, a pipe flange or nipple should be used to receive the threaded portion of the thermometer stem. When the thermometer is not to be permanently located, a cork or rubber stopper may be placed around the stem to prevent errors from air leakage. Readings should be taken at various locations in a duct so due consideration may be given to temperature stratification. Other forms of temperature measuring devices may be used, but the active part must be at least 6 in. from the duct wall.

Recording instruments may be used for testing and for making continuous records of operation. Potentiometer and Wheatstone bridge recorders for thermocouples and resistance thermometers respectively may have accuracies of ± ½ per cent of their range, or, for example, to ± 1 F in a range of 0 to 300 F. This accuracy compares favorably with that of other forms of temperature measuring devices.

AIR MOVEMENT MEASUREMENT

The quantity, velocity and pressure of air moved by a fan or flowing through a duct or grille may be determined by various methods. The instruments in common use are the Pitot tube, anemometer, direct reading velocity meter, and Kata-thermometer, 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. Electrical anemometers are also available, operating on the principle of measurement of the variation of resistance of a hot wire cooled to various degrees by air velocities past the wire. The use of calibrated nozzles, orifice plates, and Venturi meters are recognized methods, which, however, have little application in connection with ventilation practice.

Pitot Tube

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, or other type of manometer, the recorded pressure will be the differential or velocity pressure. 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 should take into account the barometric pressure and the temperature and humidity of the air measured.

Air flow in ventilation practice is generally in the turbulent range. When stratification of velocity, vortex motion, or violent eddy currents of air in ducts exist, accurate velocity pressure measurements are difficult. 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.

Anemometer

This instrument is delicate, and requires frequent calibration when accuracy is desired. The vanes of the instrument should never be touched and it should never be held in air having a velocity greater than that for which it is calibrated. Readings taken directly in a fan inlet or discharge are likely to harm the instrument because of excessive velocities. In duct measurements the same procedure is followed as for the Pitot tube. The anemometer usually reads directly in linear feet. To obtain the velocity in feet per minute, the reading must be divided by the elapsed time in minutes.

The following procedure for obtaining anemometer readings is based on research conducted at *Armour Institute of Technology* in coöperation with the A.S.H.V.E. Research Laboratory[3].

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:

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

where

V = average of corrected anemometer readings, feet per minute.
A = gross area of grille, square feet.
a = net free area of grille, square feet.
p = percentage of free area of grille expressed as a decimal.
C = a coefficient that varies with the velocity from grille and may vary slightly with type of grille. For average use, with supply grilles, C can be taken as 0.97 at velocities from 150 to 600 fpm, and as 1.00 at higher velocities.

Particular care should be exercised in the case of long, narrow grilles. The nature of the approach sometimes results in there being a narrow strip along the top or bottom of the grille through which no air will be flowing. This may be detected by holding the anemometer completely out of the air stream and then moving it slowly inward over the grille until the vanes just start to move. The distance which the vanes extend over the grille opening at this moment will indicate the width of the dead strip. Only the remaining portion of the grille should be considered in making the calculations for gross and free area.

Exhaust Grilles. The surface of the grille should be marked off and readings taken in the same manner as with supply grilles, except that the instrument should be held with the dial facing the grille, and in contact with it. The traverse should be taken at a uniform rate, allowing sufficient time in each space to minimize the percentage of error. In the case of exhaust grilles it is found that the formula

$$cfm = KVA \qquad (3)$$

[3]Measurement of Flow of Air through Registers and Grilles, by L. E. Davies (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930, Vol. 37, 1931, and Vol. 39, 1933).