where

V_m = velocity, feet per minute.
h_w = velocity pressure (Pitot tube manometer reading), inches of water.
ρ = density of air, pounds per cubic foot.

Since the velocity in a duct is seldom uniform across any section and since a Pitot tube reading indicates a velocity at only one location, a *traverse* of a duct is usual to determine the average velocity so that the flow can be computed. Suggested Pitot tube locations for traversing round and rectangular ducts are shown in Fig. 4. In general the velocity is lowest near the edges or corners, and greatest at or near the center. For this reason a large number of readings should be taken, in the case of round ducts not less than 20, along two diameters at centers of equal annular areas. In rectangular ducts the readings should be taken in the center of equal areas over the cross-section of the duct. The number of spaces should not be less than 16 and need not be more than 64. When less than 64 are taken the number of equal spaces should be such that the centers of the areas are not more than

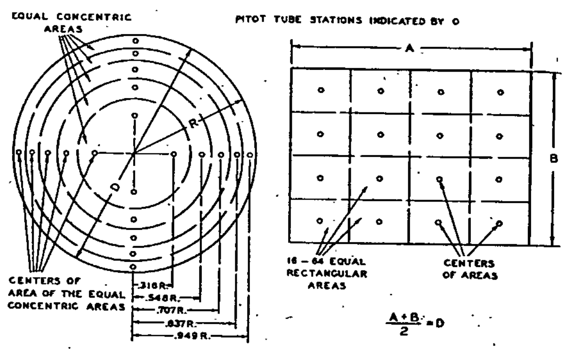

Fig. 4. Pitot Tube Traverse for Round and Rectangular Ducts

6 in. apart. In determining the average velocity in the duct from the readings given, the calculated individual velocities or the square roots of the velocity heads must be averaged. It is incorrect to use the average velocity head for this purpose. Pulsating or disturbed flow will give erroneous results and therefore, if possible, the Pitot tube should be located at least 7½ diameters down-stream from a disturbance such as that caused by a turn; or a criss-cross type of flow straightener should be installed in the duct 1½ diameters ahead of the Pitot tube[19]. Flow straighteners do not equalize flow velocity across a duct. They merely serve to improve the precision of measurements. Equalization can be effected if desirable for measuring purposes by the use of wire netting, perforated plates or cloth screens across the duct.

Many forms of Pitot tubes other than the one described have been used and calibrated[20]. A double-ended tube[21], one end pointing down-stream, and one up-stream, is sometimes used for low velocities, but it should be carefully calibrated for accurate results. A special form of this tube design consists of two straight ⅛ in. tubes soldered together, closed at the end, and with a 0.04 in. hole in each tube opposite the line of contact. This tube is useful in exploring velocities in exhaust inlets, such as hoods placed around

grinding wheels. To meet special conditions, different sized Pitot tubes which are geometrically similar to the standard tube can be used.

Plate Orifices

Application of the Pitot tube is often inconvenient when velocities are low because the resultant velocity pressures become so small that extraordinary means are necessary for measuring them. In addition, velocity surveys of the whole cross-sectional area of a duct are inexpedient when numerous test runs are in prospect. Chiefly for these reasons orifices are favored for much test work. There are two types: the plate orifice and the shaped orifice or nozzle. Plate orifices are simple to construct and convenient to use in that a frame can be made to support them in the duct such that one can be removed and another inserted when it is desirable to use an orifice of a different size.

Formulas for Orifices

In the heating and air conditioning fields it is usually convenient to obtain orifice pressure drops in inches of water column, temperatures in Fahrenheit degrees and barometric pressure in inches of mercury. The air flow is usually desired in cubic feet per minute at the existing condition, so that velocities in various ducts can be computed, and in pounds per hour so that computations of heat transferred by the air can be based on weight, temperature change and specific heat. Equation 55, Chapter 4, is applicable and for most purposes; it can be altered for convenience to read as follows:

$$Q_M = 5.2\,KD^2\sqrt{\frac{T_t}{B_t}h_w} \qquad (4)$$

where

Q_M = air flow, cubic feet per minute.
K = orifice coefficient.
D = orifice diameter, inches.
T_t = temperature of air at orifice, Fahrenheit degrees, absolute.
B_t = absolute pressure ahead of orifice, inches of mercury.
h_w = pressure drop through orifice, inches of mercury.

As most laboratories are less than 1000 ft above sea level precision is adequate in many cases if standard atmospheric pressure, 29.92 in. Hg, is assumed. Equation 4 then becomes:

$$Q_M = 0.95\,KD^2\sqrt{T_t h_w} \qquad (5)$$

After the flow in cubic feet per minute is determined, it can be expressed in pounds of air per hour by means of the relation

$$W = 60\,\frac{PQ_M}{RT_t} \qquad (6)$$

P = pressure, pounds per square inch, absolute.
R = 53.3, the gas constant for air.
T_t = absolute temperature of the flowing air, Fahrenheit degrees, absolute.

The thin-plate square-edged orifice often has a discharge coefficient K near 0.60. The exact value depends on the location of the connections, the pressure drop, the diameter ratio of orifice to pipe, and the sharpness of the