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 4 is applicable.

$$Q_M = 5.2KYD^2 \sqrt{\frac{T_f}{B_f} h_w} \qquad (4)$$

where

Q_M = air flow, cubic feet per minute.
K = orifice coefficient.
Y = expansion factor, see Fig. 5.
D = orifice diameter, inches.
d = pipe diameter, inches.
T_f = temperature of air at orifice, Fahrenheit, absolute.
B_f = absolute pressure ahead of orifice, inches of mercury.
B_a = absolute pressure after orifice, inches of mercury.
h_w = pressure drop through orifice, inches of water.

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

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

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

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

P = pressure, pounds per square inch, absolute.
R = 53.3, the gas constant for air.
T_f = temperature of the flowing air, Fahrenheit, 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 edge.[23, 24] Other information on orifices and their use is contained in Chapter 4, Fluid Flow.

Shaped orifices or nozzles have the advantage, if well made, that their discharge coefficients are close to unity so that the probability of large errors is less. Orifices of this type have been adopted for several specific

purposes, and designs are described in the Unit Heater Code[1] and Unit Ventilator Code,[2] and in A.S.R.E. Circular 13[3] entitled Standard Methods of Rating and Testing Air Conditioning Equipment. In some instances nozzles are used in multiple so that the capacity of the testing equipment can be changed by shutting off the flow through one or more nozzles. An apparatus designed for testing the air flow and capacity of air conditioning equipment is described by Wile[25] in an article in which pertinent information on nozzle discharge coefficients, Reynolds numbers, and the resistance of perforated plates is also presented. Such apparatus in some laboratories is commonly referred to as a *code tester*.

The Venturi meter is like the nozzle, except for the addition of a downstream transition section that reduces the pressure drop through the measuring apparatus.

In some cases air velocity through a duct, heater coil, or heating unit may

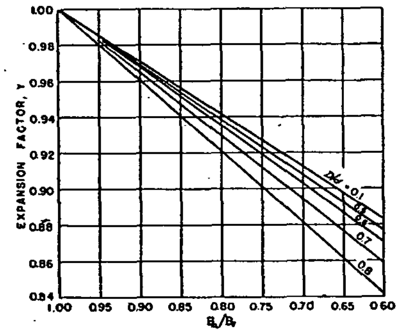

FIG. 5. EXPANSION FACTOR FOR AIR AND OTHER DIATOMIC GASES APPLICABLE TO FLANGE, RADIUS AND VENA CONTRACTA TAPS

be most conveniently estimated by computation from the heat given up by the coil, and the temperature rise (measured by thermocouples) of the air passing through. It is essential to have a uniform flow over the entire inlet and outlet of the heater at the plane of temperature measurement.

Propeller or Revolving Vane Anemometer

The propeller or revolving vane anemometer consists of a light revolving wind-driven wheel connected through a gear train to a set of recording dials that read the linear feet of air passing in a measured length of time. It is made in various sizes, 3 in., 4 in., and 6 in. being most common. Each instrument requires individual calibration. At low velocities the friction drag of the mechanism is considerable. In order to compensate for this, a gear train that overspeeds is commonly used. For this reason the correction is often additive at the lower range and subtractive at the upper range, with the least correction in the middle range of velocities. Most of these are not sensitive enough for use below 200 fpm. Anemometers of this type are practically standard for wind measurements, and may be used in large