ments are recommended. Liquids other than water are sometimes used for low pressure measurement and, when this is done, the readings must be corrected for the density of the fluid used.

For measuring pressure differences of a few inches of water, or less, U-gages are often set at an angle for scale amplification. In many gages of this type, commonly termed draft gages or inclined manometers, only one tube of small bore is used and the other leg is replaced by a reservoir. The scale is calibrated to read in inches of water, and it is necessary to use a fluid having the same gravity as that for which the gage was originally calibrated, or to apply a correction if another fluid is used. Such gages may be checked one against another. For more accurate calibration the gage may be checked against a micromanometer or a calibrating device known as a hook gage.[12] The accuracy of a draft gage is dependent on the slope of the tube, and consequently the base of the gage must be leveled carefully. It is not desirable to use a slope of less than 1 in 10. Where pressures are read under extreme conditions of temperature, and calibration is possible only at normal temperature, it is necessary to correct for the change in density of the liquid in the manometer.[13] For measuring low pressure differences to within 0.001 in. of water, very sensitive micromanometers are available, such as the Illinois or Wahlen, the Meriam, the Trimount, and the Emswiler.[14, 15]

When using a manometer or other pressure gage for measuring air flow, by means of orifices, the type of duct openings used for manometer connections and their location are important. Where velocities are low, as in some plenum chambers, or where the flow is free of large eddies and parallel to the walls of a duct, a drilled hole cleared of burrs and at right angles to the stream, is satisfactory.[16] For higher velocities, it is common practice to provide four holes or taps around the periphery of the duct. Diametrically opposite pairs of taps are connected together, and then such pairs are manifolded together.

An alternate method involves the use of the Pitot tube, shown in Fig. 3. This instrument should be pointed up-stream, parallel with the air flow. Where the flow is not axial or parallel to the side walls of the duct, a very close approximation of the static pressure and the flow direction can be obtained by a Fechheimer tube.[17]

Barometer

The simplest and earliest type of barometer consists of a glass tube somewhat more than 30 in. long filled with mercury, and inverted in a cup partially filled with mercury. The height of the mercury column in the tube above the mercury surface in the cup is a measure of the existing atmospheric pressure, except for the slight pressure of the mercury vapor in the space above the mercury in the tube. This can ordinarily be ignored.

Elaborate mercury barometers, fitted with vernier scales, are available. For precise work, corrections must be made for the thermal expansion of the mercury and of the scales.[18] The instruments are usually calibrated for 32 F mercury and 62 F scale temperature, and the correction C to be subtracted from the observed barometer's height is obtained by means of Equation 2.

$$C = \frac{h(t - 28.630)}{(1.1123t - 10978)} \qquad (2)$$

where

C = correction to be subtracted, inches of mercury.

h = observed height, inches of mercury.
t = observed temperature of the barometer, Fahrenheit degrees.

Standard atmospheric pressure at sea level is 29.921 in. Hg, and since normal atmospheric pressure decreases about 0.01 in. Hg for each 10 ft increase in elevation, it is important to make a correction if the elevation of the barometer is not that of the test apparatus. In many cases the barometric reading may be obtained from a nearby Weather Bureau Station, in which case inquiry should be made as to whether the value is for *station* or *sea level* pressure.

Atmospheric pressure may also be measured by an aneroid barometer which is easily portable. In this type, variations in atmospheric pressure deflect the thin surface of a sealed diaphragm capsule. Most commercially available aneroid barometers are not as accurate as the mercurial type, and the best require occasional recalibration. Open-scale aneroid barometers are more expensive than common mercurial barometers. Most of the pressure gages used in engineering work indicate gage pressures, that is, the

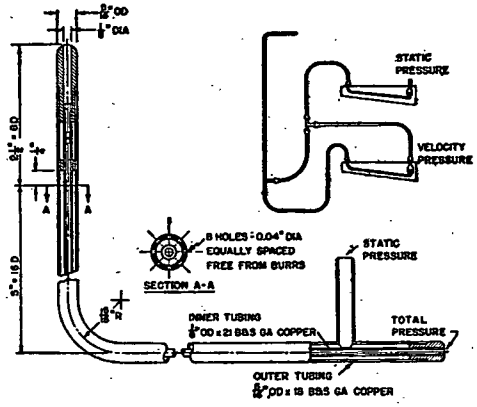

FIG. 3. STANDARD PITOT TUBE

difference between the pressure being measured and the atmospheric pressure. Such pressures are called gage pressures. Absolute pressure may be obtained by adding barometric pressure and gage pressure algebraically.

AIR FLOW MEASUREMENT

The theory of various means for measuring the flow of fluids is discussed in Chapter 4, Fluid Flow. Heating and air conditioning engineers are called upon to measure the flow of air more often than that of other gases, and usually the air is measured at or near atmospheric pressure. Under this condition, the air can be treated substantially as an incompressible fluid which implies that simplified formulas can be used with sufficient accuracy for the solution of many problems.[19]

The Pitot Tube

The construction of the Standard Pitot Tube[12] is shown in Fig. 3. The formula for velocity used in conjunction with it, is as follows:

$$V_m = 1096.5 \sqrt{\frac{h_{aw}}{\rho}} \qquad (3)$$