Atmospheric pressure may also be measured by an aneroid barometer which is easily portable. In this type, variations in atmospheric pressure bend the thin surface of a box or tube which contains a reduced pressure. The aneroid type is not as accurate as the mercurial and needs frequent calibration against one of the latter type. Most of the pressure gages used in engineering work indicate the difference between the pressure being measured and the atmospheric pressure. Pressures as measured are called gage pressures. Absolute pressure may be obtained by adding barometric pressure and gage pressure algebraically.

Pressure Gages

The Bourdon type gage is a widely used device for measuring pressures. The Bourdon tube is elliptical in cross-section and circular in form, and is connected by suitable linkage to a hand which moves over a dial. An increase in pressure tends to straighten the tube and a decrease has the opposite effect. When used with high temperature steam, the tube must be protected by a water seal. When used with ammonia it must be made of steel or other material not attacked by this substance. When used for sub-atmospheric pressure, the gage is known as a vacuum gage, and is usually graduated in inches of mercury. For pressures above atmospheric, it is termed a pressure gage and is graduated in pounds per square inch. Some are made to read in both directions and are termed compound gages. Calibration is usually made with a dead weight tester, consisting of a platform and weights resting on a piston floating on oil. From the area of the piston and the total weight resting on the oil, the pressure at all points in the fluid is determined. Adjustments are provided in the gage linkage to make necessary corrections. A correction chart may also be made and used for accurate work.

For comparatively low gage pressures or differences in pressure between two points in a duct system, the vertical *U* tube is a simple and accurate gage and is often used for test work with various fluids such as mercury, water, kerosene, or alcohol. Readings may be in inches of any of these fluids.

For measuring pressure differences of a few inches of water, or less, *U* gages are often made sloping for greater magnification of scale. In commercial gages of this type, commonly termed *draft gages*, only one tube of small bore is used and the other leg is replaced by a reservoir. Although the scale is calibrated to read in inches of water, a fluid having the density and characteristics of kerosene is often used. It is important, of course, to use a fluid having the same gravity as that for which the gage was originally calibrated, or to use a correction chart with some other fluid. Such gages may be checked one against another to detect errors in gravity of fluid. For more accurate calibration the gage may be checked against a micromanometer or a calibrating device known as a hook gage[4]. The accuracy of a draft gage is dependent on the slope of the tubes 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.

For measuring low pressure differences to within 0.001 in. of water very sensitive *micromanometers* are available, such as the Illinois or Wahlen, the Askania, and the Emswiler[5,6]. Calibration of these is impossible,

[4]Standard Test Code for Centrifugal and Axial Fans, Edition of 1938. See also Standard Code for the Testing of Centrifugal and Disc Fans (A.S.H.V.E. TRANSACTIONS, Vol. 29, 1923, p. 407; Vol. 37, 1931, p. 363).

[5]Illinois Micromanometer (*University of Illinois, Engineering Experiment Station Bulletin* No. 120, p. 91).

[6]The Weathertightness of Rolled Steel Windows, by J. E. Emswiler and W. C. Randall (A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928, p. 527).

and readings are converted to pressure units by fundamental calculations involving the specific gravity of the fluids used and the design principles involved.

The type of *pressure tip* used and its location, in cases of fluid flow, may be fully as important as the accuracy of the gage to which it is connected. In the case of low pressure air flow, the Pitot tube pointed upstream with connection made to its static pressure element is probably the best. Care should be taken to avoid taking readings where pressure can be affected by impact or eddies in the air stream.

MEASUREMENT OF AIR MOVEMENT

The problem of measuring air movement may be divided into three main parts: when confined in ducts, when circulating in free spaces, and when entering or leaving such space through openings such as grilles. Other gases might be measured by the same methods, but emphasis here will be on air measurements[7].

For determining the velocity, and therefore the volume of air flowing in a duct, such as in the test of a fan or a complete ventilating system, the Pitot tube as described in the A.S.H.V.E. Code[8] is probably most often used. At low velocities the velocity pressure head is so low that it becomes difficult to get accurate gage readings. The velocities used in many ducts are below the lower limit of determination with gages available. The relation between velocity and velocity pressure may be used to determine the range of gage required.

$$V = 1096.5 \sqrt{\frac{h_v}{d}} \tag{3}$$

where

V = velocity, feet per minute.
h_v = velocity pressure, inches of water.
d = density of air, pounds per cubic foot.

Air flow in a round duct is seldom uniform. In general, the velocity is lowest near the edges, and maximum at or near the center. In order to obtain higher velocities and more uniform flow across the measuring section, it is sometimes possible to reduce the duct to a smaller cross-section at the Pitot station by use of a long transition piece. In any case, a large number of readings along two diameters should be taken, with 20 being quite desirable. These should be taken at the centers of equal annular areas for correct determination of volumes[9]. For small pipes it is sometimes necessary to construct a Pitot tube smaller than the standard size. Such a small Pitot tube should be geometrically similar to the standard tube. Pulsating or disturbed flow will give erroneous results and every effort should be made to remove disturbances in the Pitot tube section.

Many forms of Pitot tubes other than the one described have been used and calibrated[10]. A double-ended tube[11], one end pointing down-stream,

[7]For technical data refer to Fluid Meter Reports, Parts 1—1937, 2—1931, and 3—1933 (*American Society of Mechanical Engineers*).

[8]Loc. Cit. Note 4.

[9]Loc. Cit. Note 4.

[10]Technical Notes No. 546 (*National Advisory Committee for Aeronautics*, November, 1935).

[11]The Characteristics of Double Pitot Tubes, by F. R. Ingram, E. Diez-Canseco and L. Silverman (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, November, 1942, p. 708).