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. Inquiry should be made as to whether the value is as observed or corrected to sea level.

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 barometer pressure and gage pressure algebraically.

Pressure Gages

The Bourdon type gage is a widely used device for measuring pressures. The Bourdon tube is eliptical 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 above and below atmospheric, 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 pressures within a few inches of water of atmospheric pressure, 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 calibrating device working on the U gage principle which uses hook gages and a micrometer screw. It is not considered desirable to use a slope of less than 1 to 10 in the design of these

gages. The accuracy of a draft gage is very dependent on the slope which is usually fixed by a built-in spirit level. If one side of a U gage is open to the atmosphere, the gage indicates pressure above or below atmospheric pressure. If both sides are connected, it indicates the difference in pressure existing between the two points of connection.

For measuring extremely low pressures accurately, very sensitive *micromanometers* of several types are available, such as the Chatelier, the Illinois or Wahlen and the Emswiler[2,3]. Calibration of these by a hook gage is impossible, and recourse must be made to fundamental calculations involving gravity of fluids and the principles involved. When proved accurate, a micromanometer is very useful for calibrating draft or slant gages.

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.

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[4] is probably most often used. The tube is a double tube $\frac{5}{16}$ in. outside diameter with a rounded end up-stream. The inner tube is $\frac{1}{8}$ in. inside diameter at the up-stream end, and the pressure in it is the sum of the velocity pressure and static pressure at its location in the duct. The outer tube, otherwise sealed, has 8 holes 0.04 in. in diameter and equally spaced around the circumference, and located eight diameters down-stream. A connection to this tube gives the static pressure. If both tubes are connected to opposite ends of a U gage, the gage indicates velocity pressure. At low velocities the resulting 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.

$$V = 1096.2 \sqrt{\frac{h_v}{d}} \qquad (3)$$

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

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

[3] 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).

[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).