

consistent with mechanical strength. The use of small wires also makes the thermocouple sensitive to minute fluctuations in temperature.

Other advantages of thermocouples are: they are readable at remote points, they may be made recording, and an average temperature may be readily obtained by connecting several couples in parallel.

Resistance thermometers depend for their operation upon the change of resistance of wire with change in temperature. Their use largely parallels that of thermocouples. Various metals may be used and the range is about the same as for thermocouples.

For measuring high temperatures, such as in furnaces, *pyrometers* are often used. Radiation pyrometers concentrate the radiant energy on a thermopile, and the reading is obtained on a galvanometer or potentiometer. Optical pyrometers match a narrow spectral band, usually red, emitted by the object with that from a standard electric lamp supplied with electric current.

PRESSURE MEASUREMENT

Barometer

The most accurate barometer for determining the atmospheric pressure is the mercurial type, consisting of a tube over 30 in. long closed at the top and standing in a mercury well. The barometric pressure is expressed as the height of the mercury column above the level of the mercury in the well. Such barometers are equipped with an adjustment to compensate for change in level of mercury in the well. The reading should be taken at the top of the meniscus and is obtained on a vernier scale.

Correction for variation of the density of the mercury column and for expansion of the brass scale, which are usually calibrated for 32 F mercury and 62 F scale temperature, should be made by subtracting from the observed height in inches the value of C determined by Equation 2.

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

where

C = correction to be subtracted, inches of mercury.

h = observed height, inches of mercury.

t = observed temperature of the barometer, degrees Fahrenheit.

Standard atmospheric pressure at sea level is 29.921 in. Hg. 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. 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 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 gage². 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, and the Emswiler^{3, 4}. Calibration of these is impossible, and readings are

²Standard 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).

³Illinois Micromanometer (University of Illinois, Engineering Experiment Station Bulletin No. 120, p. 91).

⁴The Weathertightness of Rolled Steel Windows, by J. E. Emswiler and W. C. Randall (A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928, p. 527).