

capacity and heat conductance of the jacket, it is more difficult to obtain the true temperature at a point with these than with the exposed etched stem type. The latter is usually preferred for test purposes. Where used to measure temperatures in a duct, it may be inserted through a cork or rubber plug. Care must be taken to locate the bulb at the point where the temperature is desired and in many cases several must be used to get a correct average.

Most mercury thermometers are calibrated for complete stem immersion. When incompletely immersed, a stem correction should be made for the most accurate determination. At ordinary atmospheric temperatures the correction is negligibly small, but it usually is important when measuring high temperatures such as those of steam and flue gas. The emergent stem correction may be calculated by the equation:

$$K = 0.00009 D (t_1 - t_2) \quad (1)$$

where

K = correction to be added, degrees Fahrenheit.

D = number of degrees on the thermometer scale which are not immersed.

t_1 = temperature indicated on the thermometer, degrees Fahrenheit.

t_2 = temperature of the non-immersed mercury column, degrees Fahrenheit.

0.00009 = difference in the coefficient of expansion of the mercury and glass.

In some cases, thermometers are calibrated for a certain depth of immersion indicated by an etched mark on the stem. Should such a thermometer be used for full immersion, a negative stem correction would be in order. In selecting a set of thermometers for a test, it is well to compare the group by immersion in a common bath and note variations. The more accurate ones can thus be selected for the more important positions. The interchanging of thermometers at inlet and outlet tends to cancel variations and therefore may result in greater accuracy. In extreme cases of small temperature differences involving large quantities of heat, it may be advisable to use thermometers graduated in tenths of degrees and mount magnifying glasses on them for accurate reading.

Since the bulb has considerable area, radiant energy may affect temperature readings¹. In measuring room temperatures, care must be taken to locate thermometers away from hot surfaces such as radiators or cold surfaces such as walls or windows. Where this is impractical, shields should be used to screen the bulb from the radiant energy.

Thermocouple

When two dissimilar metals are joined at two points and a temperature difference exists between these junctions, an electromotive force will be developed. Its magnitude depends upon the metals used and the temperature difference of the two junctions. Often the cold junction is kept at 32 F by immersion in an ice bath. In other instances, a higher temperature such as that of the atmosphere is used for this junction. By proper selection of metals, any temperature up to 2900 F may be measured. Readings are obtained by means of a potentiometer or sensitive

galvanometer which may be calibrated directly in degrees. A potentiometer balances the electromotive force against a known electromotive force with no current flowing, hence this method is independent of length and variations in resistance of leads. Calibration of thermocouples for high temperatures may be made against known melting points of metals. Radiation effects may be minimized by using the smallest size of wires 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 series.

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 at the tube meniscus is obtained on a vernier scale. When extreme accuracy is required, as in determining the thermodynamic properties of vapors at very low absolute pressures, corrections for the variation of density of the mercury column with temperature should be made. Standard density of mercury is taken at 32 F and the conversion factor from inches of mercury to pounds per square inch is 0.491.

Equation 2 may be used to make corrections for temperature variations from 32 F for mercury columns:

$$h = h_1 [1 - 0.000101 (t_1 - 32)] \quad (2)$$

where

h = corrected column at 32 F, inches mercury.

h_1 = measured height of the column, inches mercury.

t_1 = observed temperature of the column, degrees Fahrenheit.

Standard atmospheric pressure at sea level is 29.921 in. mercury. Since normal atmospheric pressure decreases about 0.01 in. mercury 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

¹Errors in the Measurement of the Temperature of Flue Gases, by P. Nicholls and W. E. Rice (A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929, p. 473).