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CHAPTER 16

MEASUREMENT AND INSTRUMENTS

Temperature Measurement, Pressure Measurement, Fluid Velocity and Volume Measurement, Humidity Measurement, Measurement of Mean Radiant Temperature, Heat Transfer Through Building Materials, Combustion Analysis, Smoke Density Measurements, Determination of Air Contaminants, Sound and Vibration Measurements

HEATING, refrigerating, and air-conditioning engineers and technicians require instruments for both laboratory and field use. Somewhat more precision is attainable and essential in the laboratory, where research and development are undertaken, than in the field, where acceptance and adjustment tests are conducted. The purpose of this chapter is to describe briefly some of the more important instruments, and to outline their uses and characteristics. In utilizing such information, a complete error analysis should be made, in order that the probable error involved with the use of a particular instrument be compatible with the desired accuracy of the final results.

TEMPERATURE MEASUREMENT[1,2]

Instruments used for measuring temperatures are listed in Table 1, together with brief comments on each. The principal instruments will be described.

Thermometers

Any device capable of indicating temperature is a thermometer, but in common usage the term *thermometer* without qualification has come to signify the ordinary liquid-in-glass temperature indicating device. Mercury-filled thermometers have a useful range from −40 F, the freezing point of mercury, to about 1000 F, at or near which the glass usually softens. Lower temperatures can be measured with alcohol-filled thermometers for which the range is about −94 F to +243 F. The better thermometers have their scales, either Fahrenheit or Centigrade, etched with acid into the glass which forms their stems.

Thermometers are calibrated during manufacture for at least two temperatures, frequently the freezing and boiling points of water, and the space between the calibration points is then divided into the desired scale divisions. The probable error for etched stem thermometers is plus or minus one scale division. For precise work, recalibration is frequently necessary to determine the proper corrections to be applied to the scale readings.

Liquid-in-glass thermometers are calibrated by the manufacturer for either complete or partial stem immersion. If a thermometer which has been calibrated for complete immersion is used at partial immersion, that is, with a portion of the liquid column at a temperature different from that of the bath, an *emergent stem correction* should be made. This correction may be calculated by Equation 1:

$$\text{Stem correction} = Kn\,(t_b - t_e) \qquad (1)$$

where

K = the differential expansion coefficient of the mercury or other liquid in the glass. K may be taken as 0.00016 for Centigrade mercurial thermometers and 0.00009 for Fahrenheit mercurial thermometers. For values of K for other liquids and specific glasses, see Reference 1.
n = the number of degrees of the liquid column emergent from the bath.
t_b = the temperature of the bath.
t_e = the average temperature of the emergent liquid column of n degrees.

A thermometer can be appreciably affected by radiation from surrounding surfaces. If the temperature to be measured is approximately the same as that of the surrounding surfaces, radiation effects may usually be ignored. If the temperature being measured differs considerably from that of the surroundings, steps should be taken to minimize the effect of radiation.[3] This is usually accomplished either by shielding or by aspiration. Shielding is accomplished by placing highly reflective surfaces between the thermometer bulb and the surrounding surfaces. However, this must be done in such a way that air movement around the bulb is not appreciably restricted.[4] Improper shielding may increase rather than decrease errors. Aspiration is accomplished by drawing a high-velocity stream of air or gas over the bulb of the thermometer.

Where it becomes necessary to use a thermometer *well* for temperature measurement within a container or pipe under pressure, care must be used to have the thermometer fit snugly and to have a high thermal conductivity liquid (oil, water, or mercury if suitable) surrounding the bulb. Such a liquid in a long, thin-walled well is advantageous in obtaining rapid response to temperature changes. The surface of the pipe or container around the well should be insulated to eliminate external heat transfer to or from the well.

Industrial-type thermometers are available for permanent installation in pipes or ducts. These instruments are fitted with metal guards to prevent breakage, and are useful for many purposes. However, the considerable heat capacity and conductance of the guards or shields may introduce errors.

The general responsibility for this chapter is assigned to TC 1.1A, Instruments and Measurements.