

INSTRUMENTS AND MEASUREMENTS

Temperature Measurement, Pressure Measurement, Measurement of Air Movement, Air Change Measurements, Measurement of Relative Humidity, Dust Determination, Heat Transfer Through Building Materials, Measurement of Heat Exchange for Comfort Conditions, Combustion Analysis, Smoke Density Measurements, Sound and Vibration Measurements

THIS chapter presents a description of many test instruments used for heating, ventilating and air conditioning tests and presents a discussion of their use.

TEMPERATURE MEASUREMENT

Changes in the intensity of heat may be determined by several methods, such as measuring the change in volume of a liquid, the change in internal pressure of a confined gas, the current set up between dissimilar metals joined in a circuit, or the change in resistance of an electrical circuit.

Thermometers

The most common method used is the change in volume of a liquid such as mercury or alcohol enclosed in glass. Mercurial thermometers may be used for measuring temperatures from -40°F to approximately 1000°F . The lower limit is set by the freezing point of mercury. Since the boiling point of mercury is only about 675°F , the space above the mercury in thermometers designed for higher temperatures must be filled with an inert gas under pressure. Alcohol thermometers may be used for temperatures from -94°F to $+248^{\circ}\text{F}$.

The more accurate thermometers have divisions etched on the stem and are preferred for test purposes due to their low heat capacity. During their manufacture, the freezing and boiling points of water are first marked while the thermometer is immersed in a test bath. The required divisions between these points, whether Centigrade or Fahrenheit, are then marked and etched on the stem. In spite of these precautions the probable error in etched stem thermometers is plus or minus one scale division, which makes calibration after manufacture necessary for most test work. Such thermometers are usually calibrated for complete stem immersion.

When incompletely immersed, a stem correction should be made. 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, Fahrenheit degrees.

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

t_1 = temperature indicated on the thermometer, Fahrenheit degrees.

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

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

Since the bulb has considerable area, radiant energy may affect the temperature readings. Whenever the thermometer bulb is subjected to radiation from a hotter or colder surface, there may be heat gain or loss through the medium whose temperature the thermometer is supposed to indicate. This error can be minimized by surrounding the bulb with a bright polished screen.

Errors may also be avoided: (a) by allowing the thermometer time to reach equilibrium, (b) by providing sufficient circulation to give a true average temperature of the medium observed, and (c) by reading with the eye at the same level as the top of the liquid, i.e., avoiding parallax.

Industrial type thermometers are available for permanent installations in ducts and pipes. Because of the heat capacity and conductance of the jackets of these instruments, they do not follow the fluctuations in a medium of varying temperature as well as the etched stem thermometer.

Thermometer Wells

Where temperatures of fluids or gases in vessels or conduits are to be measured, it is often necessary to resort to thermometer wells. These are especially designed to contain thermometers and thermocouples. Since the well separates the temperature sensitive element from the medium to be observed, large errors may result from their improper use. These errors may be due both to poor heat transfer from the wall of the well to the sensitive element, and also to the tendency of heat to travel along the length of the well itself. To improve heat transfer in the case of thermometers, the well should be filled with a liquid of minimum practical viscosity. For medium temperatures a light mineral oil is satisfactory. Excessive conduction can be prevented by making the projecting head of the well as small as possible and the walls as thin as possible. After the thermometer is in place, the external head of the well and the wall of the conduit in the vicinity of the well should be covered with insulating material.

Thermocouples and Resistance Thermometers

When two dissimilar metals are joined at two points and a temperature difference exists between these junctions, an electromotive force is developed. By maintaining the cold junction at a constant temperature (or providing equivalent electrical compensation), the magnitude of the electromotive force developed is a direct measure of the temperature of the warm 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 in degrees. If a potentiometer is used, there is no current flowing through the thermocouple wires at the time of measurement and therefore the resistance of the thermocouple circuit does not affect the accuracy of the reading. If a galvanometer is used instead of a potentiometer, the instrument is usually built with a high internal resistance to minimize the effect of the resistance of the thermocouple circuit and, also, special lead wires of known resistance are used to connect the galvanometer to the thermocouples. The basic potentiometer circuits are shown in Fig. 1. The thermocouple leads A-B are so connected that their polarity opposes that of battery C. If the position of E on the graduated slide wire rheostat DF is adjusted until galvanometer G shows no current flowing, resistance DE will indicate directly the voltage generated by the thermocouple. In order to correct for variations in voltage from battery C,