Since the bulb has considerable area, radiant energy may affect temperature readings [2]. 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 impracticable, bright, polished shields should be used to screen the bulb from the radiant energy.

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.

Two types of industrial thermometers for permanent installation in ducts or pipes are shown in Fig. 1, and consist of a glass thermometer protected by a metal case. The better grades have metal scales made specially for each instrument. These are ruled in the same manner as

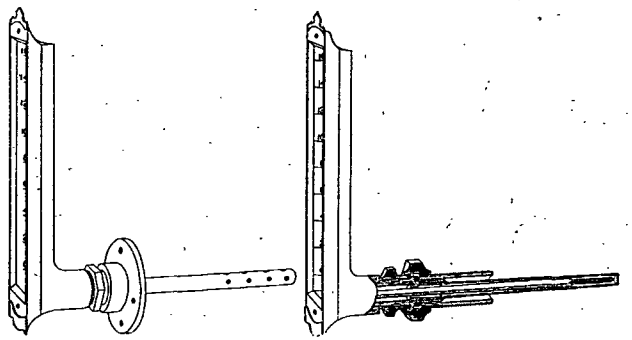

FIG. 1. INDUSTRIAL THERMOMETERS FOR PERMANENT INSTALLATION

described for etched stem thermometers. Due to the heat 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.

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 they separate the temperature sensitive element from the medium to be observed, large errors may result from their improper use [3]. 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 void should be filled with a liquid of minimum practical viscosity. At the well mouth, the stem should be packed to check evaporation and heat transfer to the atmosphere. To reduce the temperature gradient over the length of the well, the wall of the conduit should be carefully insulated in the area surrounding the observation point.

Thermocouples

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

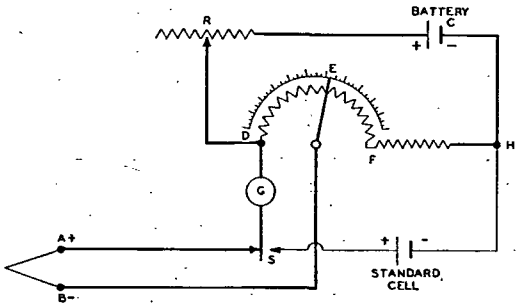

FIG. 2. BASIC CIRCUIT AND CONNECTIONS FOR THERMOCOUPLE AND POTENTIOMETER

lead wires of known resistance are used to connect the galvanometer to the thermocouples. The basic potentiometer circuits are shown in Fig. 2. 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, switch S is momentarily thrown over to the standard cell circuit and rheostat R is then adjusted so that the galvanometer shows zero current. Battery C then exerts the known voltage of the standard cell at DH.

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. Wires of No. 33 B & S gage are small enough to be sensitive and to minimize radiation effects while still rugged enough for many purposes. By the use of thermocouples, temperatures at remote points may be indicated or recorded on conveniently located instruments; average temperature may be readily obtained by connecting several couples in parallel or in series; and tem-