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. The effect of radiation upon thermocouple readings may be eliminated by using several couples of different diameters and plotting the readings obtained against the diameters. The true temperature reading is obtained by drawing a smooth curve through the plotted points and extending the curve to intersect

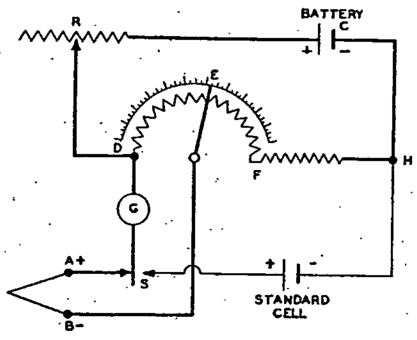

FIG. 1. BASIC CIRCUIT AND CONNECTIONS FOR THERMOCOUPLE AND POTENTIOMETER

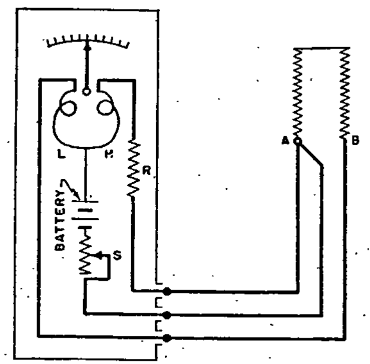

FIG. 2. TYPICAL RESISTANCE THERMOMETER CIRCUIT AND CONNECTIONS

the zero diameter axis[4]. The temperature reading at point of intersection is the true temperature.

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 temperatures may be obtained within thin materials, narrow spaces, or otherwise inaccessible locations.

Thermocouples in series with every alternate junction maintained at a common temperature will give an emf which, divided by the number of couples to give the average emf[5] per couple, may be used to find the average temperature.

Thermocouples in parallel having the similar metals of a number of couples connected together and run to a common cold junction will cause an indication on a potentiometer which is the true emf only if the electrical resistances of the parallel junctions are the same[5, 6].

Temperatures of surfaces below red heat are difficult to determine by any other means than thermocouples. For this purpose, a thermocouple of fine wires is preferable to minimize the possibility of error due to the conduction of heat along the wires. It may be attached to a metal surface in any of several ways. For permanent installations, soldering, brazing or peening may be desirable. A small hole is drilled for the peening

operation; the thermocouple is inserted and the metal is peened to retain it. The fact that the thermocouple is in electric contact with the surface is unimportant in usual circuits. For temporary arrangements, couples may be attached by means of surgical or cellophane tape. For many boiler or furnace surfaces, furnace cement serves very well. The thermocouple may be attached by means of the cement when the surface is cold and must be treated gently and usually supported until the cement dries, due to heat, and hardens—after which it has ample strength. It is good practice to use as little cement as possible, and also to plaster the wires to the surface for an inch or so from their junction to avoid errors due to heat conduction along the wire. Electric insulation between the wires should be perfect except at the junction since, otherwise, the indicated emf will be between those existing at the junction and at the short circuit.

Resistance thermometers depend for their operation upon the change of electric resistance of metal with change in temperature. The resistance generally increases with rising temperature. Their use largely parallels that of thermocouples, although readings tend to be unstable above 950 F. Two-lead temperature elements are not recommended, since they do not permit correction for lead resistance. Three leads to each resistor are necessary to obtain consistent readings.

A typical circuit used by several manufacturers is shown in Fig. 2. In this design a differential galvanometer is used, in which coils L and H exert opposing forces on the indicating needle. Coil L is in series with the thermometer resistance AB, and coil H is in series with the constant resistance R. As the temperature falls, the resistance of AB decreases allowing more current to flow through coil L than through coil H. This causes an increase in the force exerted by coil L, pulling the needle down to a lower reading. Likewise, as the temperature rises the resistance of AB increases, causing less current to flow through coil L than through coil H. This forces the indicating needle to a higher reading. Rheostat S must be adjusted occasionally to maintain a constant flow of current.

As compared to the thermocouple the resistance thermometer does not require a cold junction, and it can be simply scaled for more accurate measurements; but, generally because of its construction it is more costly and is apt to have considerable lag. It gives best results when used to measure steady or slowly changing temperature. For accurate results the entire thermometer coil must be exposed to the temperature to be measured.

Pyrometers

For measuring high temperatures, 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 require visual matching of a narrow spectral band, usually red, emitted by the object with that from a standard electric lamp.

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