peratures 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 [4] 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 [4, 5].

The temperature of the surface is at best difficult to obtain accurately [6]. The thermocouple is most readily adaptable for this purpose. In a metal surface, a common method is to peen the couple into a small drilled hole, bearing in mind that the temperature indicated is that existing at the last point of junction in the couple. Other methods involve

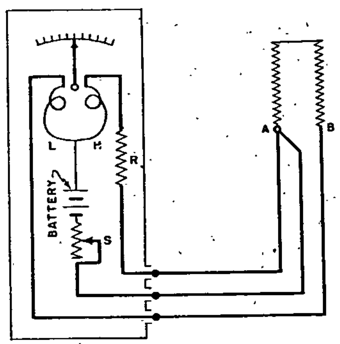

FIG. 3. TYPICAL RESISTANCE THERMOMETER CIRCUIT AND CONNECTIONS

fastening the couple to the surface with adhesive cellophane, or cementing the couple with litharge in a surface scratch, and grinding it flush with the surface. Wires may also be fastened to the surface by brazing, care being taken to add as little extra metal as possible. This is a useful method for obtaining the temperature of cast-iron heating surfaces.

In any of these methods the leads should be of as fine wire as practicable, since conductance along the leads to the couple may be a source of considerable error.

Resistance thermometers depend for their operation upon the change of resistance of metal with change in 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. 3. 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.

Instruments of this type are frequently connected through a selector switch to a number of thermal resistor elements and used to indicate temperatures in remote locations in large buildings. The direct reading feature is advantageous in this case.

Pyrometers

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 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 well. Such barometers are equipped with an adjustment to compensate for change in level of mercury in the well. The reading should be taken at the top of the meniscus and is obtained on a Vernier scale.

Correction for variation of the density of the mercury column and for expansion of the brass scale, which are usually calibrated for 32 F mercury and 62 F scale temperature, should be made by subtracting from the observed height in inches the value of C determined by Equation 2.

$$C = \frac{h\,(t - 28.630)}{(1.1123\,t - 10978)} \qquad (2)$$

where

C = correction to be subtracted, inches of mercury.
h = observed height, inches of mercury.
t = observed temperature of the barometer, Fahrenheit degrees.

Standard atmospheric pressure at sea level is 29.921 in. Hg. Since normal atmospheric pressure decreases about 0.01 in. Hg 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 Bureau Station, in which case inquiry should be made as to whether the value is as observed or corrected to sea level.

Atmospheric pressure may also be measured by an aneroid barometer, which is easily portable. In this type, variations in atmospheric pressure bend the thin surface of a sealed box or tube. The aneroid type is not as accurate as the mercurial and needs frequent calibration. Most of the pressure gages used in engineering work indicate the difference between the pressure being measured and the atmospheric pressure. Such pressures are called gage pressures. Absolute pressure may be obtained by adding barometric pressure and gage pressure algebraically.