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# LXX. A potentiometer for thermocouple measurements

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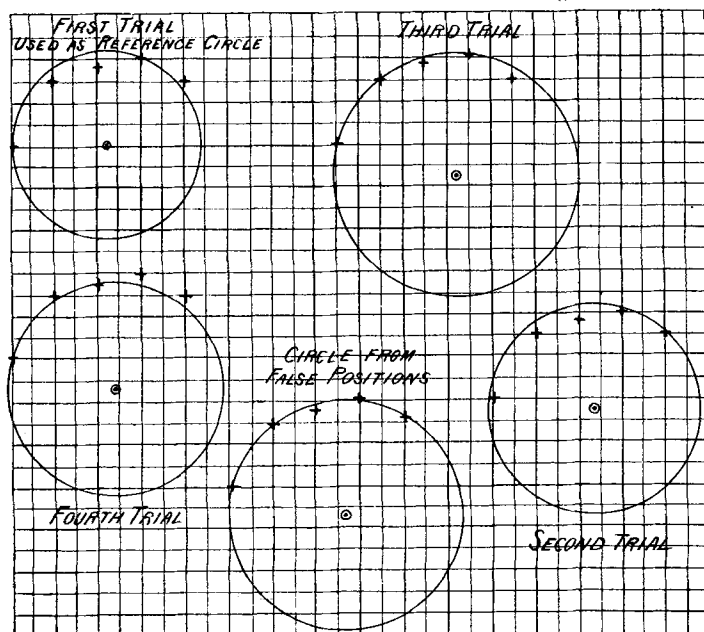


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approximation and the remaining three trials to get a second approximation. The diagram, however, shows that little

General Method of False Position.—Best Circle through Five Points.



could be gained by this extra labour, and this illustration of the circle fully suffices to indicate the comparative ease with which the new method may be used on a hitherto unsolved type of problem. The labour would not have been much greater had we required a circle (or any other three-constant curve) through even a dozen points.

### LXX. A Potentiometer for Thermocouple Measurements.

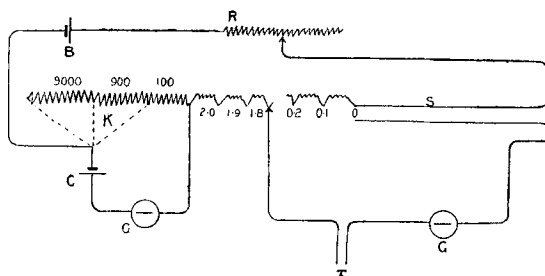
By R. A. LEHFELDT\*.

TO make a satisfactory potentiometer for thermoelectric work, it is essential that it shall not introduce a high resistance in the circuit of the couple and galvanometer. Most of the potentiometers in the market, which answer well enough for comparing voltaic cells, fail in this respect. I have therefore devised an instrument which is shown schematically in fig. 1. From the positive terminal of the accumulator B current flows to the switch K by means of [which it can be

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sent through  $100\omega$  or  $100 + 900$  or  $100 + 900 + 9000$ , in order to get three grades of sensitiveness: it then passes through 20 coils of  $0.1\omega$  each, a slide-wire of a little more than  $0.1$  ohm,

Fig. 1.



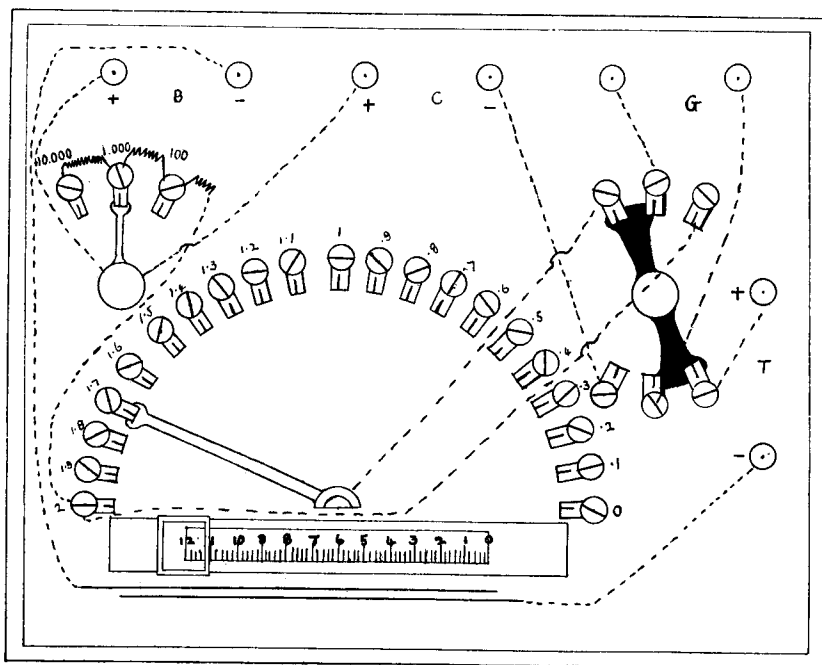
and through the adjustable resistance  $R$  back to the accumulator. The fixed resistance of 100, 1000, or 10,000 ohms is shunted by a cadmium cell  $C$  and galvanometer  $G$ , and  $R$  adjusted till the galvanometer is balanced. The thermocouple  $T$  with galvanometer  $G$  is put across any number of the tenth-ohm coils, and any fraction of the slide-wire. Of course two galvanometers, as shown in the diagram, are not necessary: a double pole-switch puts the actual instrument into either circuit as desired.

The voltage on the ends of one of the tenth-ohms (taken as unit) is then 1000- 10,000- or 100,000th part of the cadmium, *i. e.*, approximately 1000, 100, or 10 microvolts, according to the position of  $K$ .

Fig. 2 represents the actual instrument. The greatest care has been taken to avoid accidental thermoelectromotive forces, which are the chief trouble in using thermocouples. The couple I have actually used so far is constantan copper, which gives about 4000 microvolts between  $0^\circ$  and  $100^\circ$ . The only metals used in the measuring circuit are copper and manganin. All the coils are of the latter metal; the slide-wire is of gilt manganin; the galvanometer connexion is made by a short bridge between the slide-wire and a similar galvanometer wire. (These two wires are shown in the figure by the side of the scale, though actually underneath it.) The slider makes contact always, a separate key being used to put the galvanometer in circuit. The potentiometer is inclosed in a wooden case, lined with thick sheet copper and filled with paraffin-oil to keep the temperature constant, and the two points where the copper thermocouple leads join the manganin measuring circuit are carefully buried deep down in the interior of the box and near together.

The sliding contact is carried by a block sliding on two steel bars: it is moved by a steel rod with clamping and fine adjustment screws, and its position read through a lens by means of a vernier graduated in fortieths of a millimetre.

Fig. 2.



As the wire is 100 millims. long the smallest reading is  $\frac{1}{4000}$  of the unit, which, as stated above, may be 1000, 100, or 10 microvolts; and as there are 20 tenth-ohm coils, the smallest reading is  $\frac{1}{80,000}$  of the largest.

The fineness of reading is, as a matter of fact, limited by the sensitiveness of the galvanometer used.

All the working parts are inclosed by a plate-glass lid through which only the handles project.

Outside the potentiometer itself the apparatus used consists of the accumulator (sometimes two or more); the adjustable resistance R; the cadmium cell; galvanometer—a highly sensitive D'Arsonval of about 20 ohms, made by the Cambridge Scientific Instrument Co.; and galvanometer key. The latter is of the usual short-circuiting reversing type, but unusually small, made of copper, and inclosed in a box from which

only the ebonite studs project, for the better avoidance of thermoelectric effects.

To calibrate the instrument the procedure is as follows:—

(i.) The  $100\omega$ ,  $1000\omega$ , and  $10,000\omega$  resistances are compared directly with standards. To allow of this and similar operations, the heads of all the studs in the instrument carry screws. The comparison was kindly made for me at the National Physical Laboratory.

(ii.) Each tenth-ohm is compared with the succeeding one by the usual method for comparing nearly equal resistances; the slide-wire is compared with the first tenth-ohm in the same way. During these operations current is led through the coils and the voltage taken off at the same points as when the potentiometer is ordinarily in use.

(iii.) Groups of ten tenth-ohm coils in series are compared with a standard ohm by the method described in the following paper.

(iv.) Further, as a check on the results, two groups of ten tenth-ohm coils were measured at the National Physical Laboratory in the usual way. These measurements are of no direct use, however, as in making them current is led into and out of the coils at the points ordinarily used for taking off the voltage; hence the result differs from that obtained in (iii.) by the resistance of the studs, which is one or two thousandths of an ohm.

(v.) The slide-wire is calibrated.

It would be a convenience in calibrating to provide an additional terminal, connected to the point of junction of the last tenth-ohm with the hundred-ohm coil, as this would enable one to lead in current under the usual working conditions without passing the high-resistance coil: this is desirable when calibrating the tenth-ohms, as it is safe to use pretty large currents through them. Otherwise I have found the working of the instrument satisfactory.

Before measuring a thermocouple, two tests should be made. First, the galvanometer-key should be pressed half-way down, so that the galvanometer-circuit is broken. The needle will probably swing a little. If it swings equally on each side of its previous position of rest, there is no thermoelectric effect in the galvanometer. Second, a short piece of copper wire should be put across the thermocouple terminals and the battery-circuit broken: if then (with double-pole switch set to the thermocouple circuit) on pressing the galvanometer-key there is no deflexion, this shows absence of disturbing thermoelectric effects in the rest of the apparatus. The measurement may then be proceeded with.