Self-checking Galvanometer Pyrometer

BY H. F. PORTER,* E. E., TRENTON, N. J.

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MUCH has been written relative to the errors involved in the use of a galvanometer for measuring thermocouple electromotive forces. In general, it may be said that accuracy with a galvanometer is secured only at the sacrifice of durability, unless manual adjustment is made in the operation of the instrument to overcome the errors of resistance and resistance changes. The pyrovolter and the potentiometer both require manual adjustment for every reading, readings being taken on a "null" method.

To the end that some of these balances may be eliminated and only an occasional balance be made as a check reading, the "continuously deflecting pyrovolter" was developed. Essentially, the operation of the continuously deflecting pyrovolter is to determine the resistance of the thermocouple circuit, though its value is not noted or indicated, then throwing in series with the thermocouple sufficient resistance to bring the sum up to some standard value for which the indications of the galvanometer will be correct. This result may, however, be accomplished in a somewhat simpler manner, for which general method patents are now in the course of application.

If we devise a galvanometer circuit so that by means of a simple adjustment the resistance of the entire circuit will be rendered equal to some constant predetermined value, we may rely on the galvanometer to give correct e.m.f. indications (assuming that the errors of temperature resistance coefficient and cold junction have been properly allowed for), and will indicate temperature continuously where the e.m.f. measured is developed by a thermocouple.

In Figs. 1 and 2, there is in series with the galvanometer of resistance g the thermocouple of resistance X and the rheostat of total resistance S. To operate the instrument, that is, to make a check to compensate for couple resistance, a button is depressed which connects points M and N, as shown in Fig. 1, normally separated, and disconnects points P and Q,

* Secretary, Pyrolectric Instrument Co.

normally engaged in contact. The slider on the rheostat is adjusted until the resistance a is zero and the deflection D of the meter is at its maximum. This deflection is noted, and, still depressing the button, the slider is adjusted until a deflection equal to $D/2$ is obtained. The button is now released, closing the connection between points P and Q and breaking the contact of M and N, as shown in Fig. 2. The resistance R_3 of the entire circuit after this adjustment is complete equals S, a

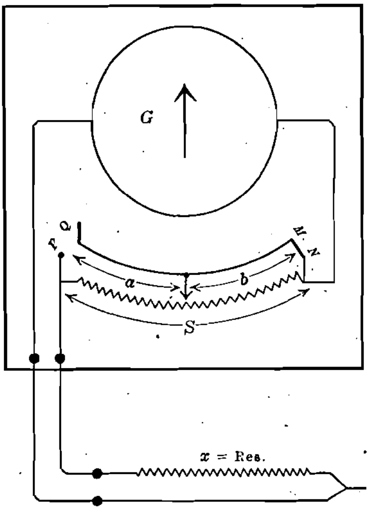

FIG. 1.

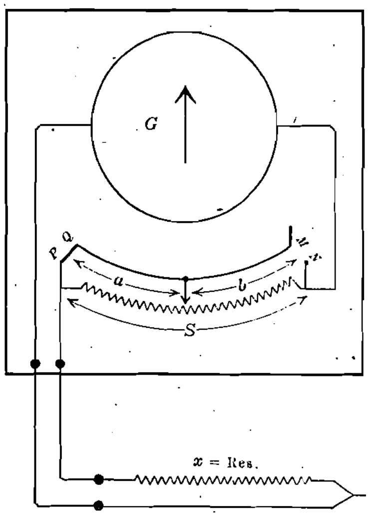

FIG. 2.

constant value equal to the total resistance of the rheostat shown. This is easily proved as follows:

Call the resistance of the entire circuit in Fig. 1, R_1, that is, when a is zero

$$R_1 = g + X \tag{1}$$

For deflection $D/2$, the circuit resistance is R_2

$$R_2 = g + X + a \tag{2}$$

Since adding resistance a to the circuit halved the current flowing, and hence the deflection, the circuit resistance must have been doubled when the adjustment was complete or $2R_1 = R_2$. By substitution from formulas (1) and (2), $2(g + X) = g + X + a$; whence $g + X = a$. When the button is released and connections are made between P and Q, simultaneously breaking the junction between points M and N, the circuit resistance R_3 becomes $R_3 = b + g + X$; and since $g + X = a$, $R_3 = b + a$.

By definition of a and b, they are the component parts of the rheostat and $a + b = S$; so that $R_3 = a + b = S$ which is the result it was desired to prove.

The following characteristics of this circuit may be of interest. Maximum allowable resistance in thermocouple circuit external to instrument is $M = (s - g)$. The e.m.f. range of the instrument is given by $E = S\,I$, where I is the current required to deflect the galvanometer to full scale.

The relative error of setting is small in direct proportion as $(b + X)$ is small in comparison with g. Also the error of setting for $D/2$ is inversely increased with reduction in the value of D.

Many variations of this type of circuit are possible, though their method is essentially the same as that outlined. It must be remembered that check readings can only be taken when the conditions are such that the e.m.f. of the couple is practically constant, but there is no need for such checks except when it is supposed that the circuit resistance may have changed, changes being due to temperature resistance coefficient of leads, couple, of galvanometer coil, depth of immersion of couple, corrosion of some part of the circuit reducing its cross-sectional area of conductor or adding contact resistance, or the shortening of the couple or couple leads. If the rheostat S is made of manganin or some alloy of practically negligible temperature resistance coefficient, the instrument is free from errors due to change in the resistance of the galvanometer coil, and hence the instrument is free from errors of indication due to temperature changes of the instrument coil.

The main objection to an instrument of this type is that it can only be used conveniently with one couple at a fairly constant depth of immersion and temperature. It is impractical to employ it with several couples and a selective switch or other similar device, unless all the couple circuits are of strictly the same resistance—a circumstance that is difficult to secure and almost impossible to maintain. The chief advantages are the elimination of any form of cell, dry or standard, from the instrument circuit and continuous deflection, with only occasional manual adjustment.

The circuits offer unusual possibilities for the instruction of students in electrical measurements. Knowing the current sensitivity of the galvanometer at full scale and the value of the rheostat, it is possible to determine the galvanometer resistance, battery resistance, and voltage, and to correct a millivoltmeter from all errors due to line drop or extraction of current from a high resistance shunt.