A Method for Eliminating the Effect of all Connecting Resistances in the Thomson Bridge.[1]

By F. Wenner.

The arrangement of conductors for a Thomson bridge is shown in Fig. 1. Here the low resistances under comparison are designated by X and N, the resistances for the main ratio by A and B, and of the auxiliary ratio by α and β. Farther, the connecting resistances from the points where the current and potential terminals divide to the terminals of the ratio sets are designated by x_1, x_2, n_1 and n_2. These letters are used both to designate the conductors and to represent the values of their resistances, C represents the value of the resistance between X and N from branch point to branch point while L designates the low resistance in parallel with the auxiliary ratio. If then the conductors are all *linear* and the bridge is balanced we have the following relation between the resistances:[2]

$$X = N\frac{A + x_1}{B + n_1} + \frac{A + x_1}{B + n_1} C\frac{\alpha + x_2}{\beta + n_2 + \alpha + x_2} - C\frac{\beta + n_2}{\beta + n_2 + \alpha + x_2}. \quad (1)$$

This equation may be put in a more convenient form if we substitute

$$\frac{A}{B}(1 + a) \text{ for } \frac{A + x_1}{B + n_1}, \quad \frac{A}{B}(1 + b) \text{ for } \frac{\alpha + x_2}{\beta + n_2},$$

and

$$D \text{ for } \frac{C}{N}\frac{\alpha + x_2}{\alpha + x_2 + \beta + n_2}$$

which give

$$X = N\frac{A}{B}[1 + a + D(a - b)]. \quad (2)$$

If by suitable adjustments a and b can be made so small as to have no appreciable effect this reduces to the equation for a simple bridge. In order to make these adjustments possible, low resistances, forming a part of x_1, x_2, n_1 and n_2, are connected between the potential terminals and the ends of the ratio sets. These resistances can be varied continuously, or in small steps, at least on one side of each ratio.

Starting with the ratio A/B and X/N approximately equal

1. With q and q' as branch points, the bridge is balanced by an adjustment of x_1 or n_1.

[1] Abstract of a paper presented at the Washington meeting of the Physical Society April 21 and 22, 1911.

[2] Wm. Thompson, Phil. Mag., 24, p. 149, 1862.

2. With p and p' as branch points and the connection L between X and N open[1] the bridge is balanced by an adjustment of x_2 or n_2.

3. With p and p' as branch points and the connection L between X and N restored, the bridge is balanced by an adjustment of N or a proportional adjustment of the main and auxiliary ratios.

Where the connecting resistances are small in comparison with the ratio sets and starting with the three ratios X/N, A/B and α/β approxi-

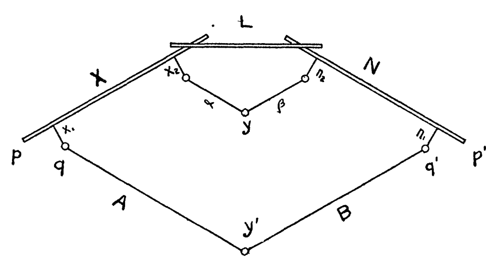

FIG. 1.

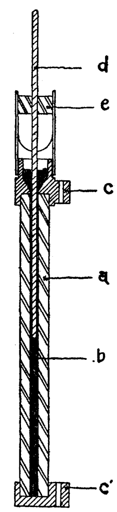

FIG. 2.

mately equal; the first operation makes a negligibly small, the second makes b equal to a, and the third fulfills the conditions of the fundamental equation. The three adjustments then give

$$X = \frac{A}{B} N, \tag{3}$$

which is the equation for the corresponding simple bridge.[2]

As the three adjustments are not entirely independent, any change in making the second or third disturbs the first slightly, it may be necessary in some cases to repeat them in the same order using those already made as first approximations. Where the measurements are made in this way the accuracy is as high or higher than where any of the connecting resistances are determined and the corrections applied, while the time and attention necessary for making the measurements and calculations are considerably less.

[1] J. H. Reeves, Proc. Phys. Soc. London, 14, p. 166, 1896.

[2] W. Jaeger and H. Diesselhorst, Wiss. Abh. d. P. T. R., 4, p. 120, 1906.

The conditions that must be fulfilled on order that a four terminal resistance may have a definite value are pointed out, Farther it is shown that there can be but three definite values and one of these is the sum of the other two. If one of the three values is zero the effect is the same as if the conductors were in the form of a wire and we shall call it *linear* to distinguish it from the other case which we shall call *non-linear*.

In using the Thomson bridge with non-linear conductors the current through the potential connections to or from the ratio sets causes a change from the normal current distribution in such a way as to destroy the relations given by the fundamental equation. A more extended theory is given showing that, under certain conditions easily realized, correct values are obtained whether the resistances are linear or non-linear and that, if the adjustments here outlined are carried out, equation (3) gives the relation between the resistances with which we are concerned even in those cases in which equations (1) and (2) are not valid.

As the success of the method depends upon having suitable variable low resistances, the form used which was developed jointly by J. H. Dellinger and the author, is shown in section in Fig. 2. Here the letters have the following significance; a a hard rubber tube, b mercury, c and c' copper terminals amalgamated where they come in contact with the mercury, d an amalgamated copper rod, e a spring clamp for holding the copper rod in position. Electrical connection is made through the terminal blocks c and c' and the resistance is varied by changing the position of the copper rod.

Where alternating current is used the conditions which a four terminal conductor must fulfill in order that it have a definite inductance as well as resistance are pointed out. Farther, it is shown that where the measurements are carried out as outlined above, adjusting inductances as well as resistances, the same simple relations are obtained, both between the inductances, and the resistances. Unless the inductances as well as the resistances are adjusted a balance can not be obtained except with non-inductive conductors.

If a direct current galvanometer is used and commutated synchronously with the current or the galvanometer is of the type having the field excited by a current from the same source as the test current it is possible by adjusting resistances only to get a zero deflection but this does not necessarily signify that the bridge is balanced.