ELECTRICAL MEASUREMENTS. PART II - ADVANCED. INSTRUCTION PAPER. PP. 53-92

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GEORGE W. PATTERSON

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ELECTRICAL MEASUREMENTS

PART II—ADVANCED

INSTRUCTION PAPER

PREPARED BY

GEORGE W. PATTERSON, S.B., Ph.D.

HEAD, DEPARTMENT OF ELECTRICAL ENGINEERING,
UNIVERSITY OF MICHIGAN

AMERICAN SCHOOL OF CORRESPONDENCE

CHICAGO ILLINOIS

U.S.A.

ELECTRICAL MEASUREMENTS

PART II—ADVANCED

MEASUREMENT OF CAPACITY

Ballistic Galvanometer. In the measurement of the capacity of a condenser by the methods given in the subsequent pages, the charge of electricity from the condenser is allowed to flow as a momentary current through a galvanometer, giving the suspension a sudden *kick*. In order to calculate from this deflection the *quantity of electricity* in the condenser, it is necessary to assume that the galvanometer suspension is so heavy that it will not have moved very far before the charge has completely passed. This requisite, viz, a heavy suspension, is the distinguishing feature of the *ballistic* type of galvanometer. (See Fig. 7, Part I.)

As a rule the methods of measurement involve only a comparison of the deflections produced in the ballistic galvanometer by charged condensers of known and unknown capacity, so that, as long as the capacity of a standard condenser is known, the unknown factors, the galvanometer constant, etc., are unimportant. Nevertheless it may be instructive to know how these unknowns can be determined and the deflections can be made to give the actual quantity of electricity in the given condensers.

Because of the fact that the deflection of the galvanometer is not proportional to the current which produces the deflection, it is necessary to know the factor called the *constant* of the galvanometer before measurements can be taken. This constant is used in various forms but can be briefly stated as *the constant ratio between the current and the deflection produced by it.* When put in more definite form it can be given as follows:

$$K = \frac{2\,I\,D}{d}$$

in which I is the current flowing in the galvanometer, D is the distance from the galvanometer mirror to the scale, and d is the deflection produced on the scale.

With this in mind let us consider *how to find the quantity of electricity Q from the throw θ of the galvanometer, the galvanometer contant K, and the half period of the suspension.*

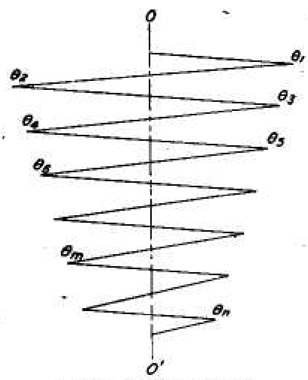

Fig. 36. Damping Diagram.

As has been stated above, while the quantity Q is passing through the galvanometer, short though it may be in duration, it constitutes a current and the magnetic effect of this current exerts a turning moment on the coil.

If I represents the mean value of this current, then the mean moment of force $\overline{Fh}$ acting on the coil while the current is flowing is

$$\overline{Fh} = I \, \mathbf{H} \, A$$

in which $\mathbf{H}$ is the strength of the field and A is the area of the galvanometer coil. If τ is the duration of the discharge, then the moment of force times the time can be given by

$$\overline{Fh}\tau = I\tau \mathbf{H} A = Q\mathbf{H}A$$

in which Q is the quantity of electricity, equal to $I\tau$.

If the moment of inertia M of the suspension and the angular velocity, which is given to it by this *kick*, are taken into consideration, the quantity of electricity Q may be obtained from the above equation as follows:

$$Q = K\omega \frac{M}{T_o}$$

in which ω is the angular velocity and T_o is the torsion constant of the suspension. By taking the half period of the suspension, which is easily obtained by counting the time of a given number of swings, and expressing ω in terms of the angle of throw θ, the expression for the quantity of electricity is given by the following equation:

$$Q = \frac{K\theta t}{\pi}$$

in which K is the galvanometer constant, θ the angle of throw (obtained by dividing the deflection d by twice the distance from mirror to scale D), t the half period of the suspension, and π 3.1416.

For accurate work θ must be multiplied by a damping factor $\sqrt{\rho}$, derived as follows: With the suspension swinging freely, Fig. 36, take a deflection θ_m, then after a given number of swings (n-m) take another deflection, θ_n; ρ is the (n-m) root of the ratio $\frac{\theta_m}{\theta_n}$.

Condensers. A condenser consists in its simplest form of two metal sheets separated by a nonconducting material, Fig. 37. If an e. m .f. is applied to the two metal sheets, they will take a static charge, one positive and the other negative. The nonconducting material is called a *dielectric*, as the electric force acts through it (*dia* meaning through). The capacity of such a condenser is proportional to the

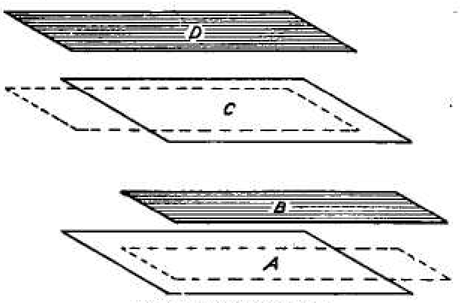

Fig. 37. Condenser Sheets.

area of the sheets and inversely proportional to the thickness of the dielectric. If the condenser is in the form of a glass jar coated outside and inside with tin foil, the arrangement is called a *Leyden jar*. A considerable portion of the surface near the edges of the jar should be free from the tin foil coating in order that the charge may not leak over the surface of the glass. The best condensers are made of many sheets of mica with sheets of tin foil interlarded, every alternate one being connected to one, and the others to the other terminal of the condenser, Fig. 38. By using many sheets of tin foil the capacity is increased in proportion to the total area. Mica is an excellent material for the dielectric as its resistance is extremely high, and very thin sheets have enough strength to withstand the mechanical stress due to the electric charges without breaking down. The mica and tin foil are clamped in place and the whole immersed in melted paraffin and then withdrawn, carrying out a coating of paraffin which protects the condenser from the effects of moisture. Several condensers of assorted capacities are frequently mounted in one box, Fig. 39. A 1 m. f. box will frequently have condensers of 0.5, 0.2, 0.1, 0.1, 0.05

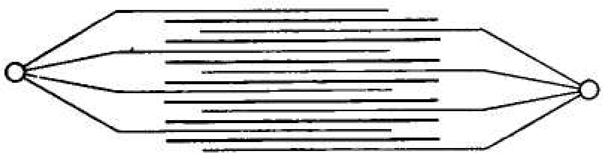

Fig. 38. Simple Condenser.

and 0.05 microfarad, Fig. 40. Cheaper condensers have paraffined paper or other materials in place of mica; but are usually poor since the dielectric, though it does not break down, is apt to yield gradually to the strain of the charge, producing an effect which is known as *absorption of the charge.* It seems as though some of the charge had been lost for when the condenser is discharged, less charge comes out than was put in. It is true that real leakage causes a loss of part of the charge, but we find also that a poor condenser, if set aside after being discharged, will, on a later test, show a small charge which has come from the gradual return of the dielectric to its original state. The Leyden jar (glass dielectric) absorbs a considerable portion of its charge. Standard condensers are sometimes made with massive plates of metal and with air, which has no absorption, as the dielectric. They are very expensive and have small capacity. For practical purposes

Fig. 39. Variable Condenser.

the best condensers have mica for the dielectric, for mica shows almost no absorption of the charge.

Single conductor submarine and land cables have the properties of condensers, the water acting as the second sheet in the case of the

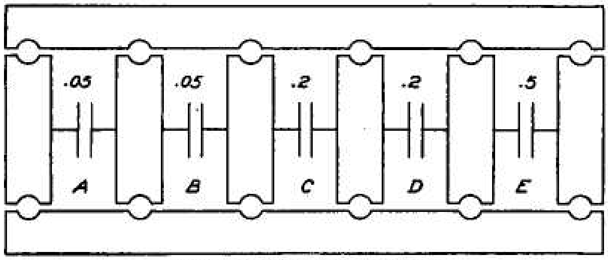

Fig. 40. Plan of Variable Condenser.

former, and the usual lead covering in the case of the latter. In telephone cables, each pair of wires and the insulation between make up a condenser. These cables almost always show considerable absorption of the charge.

Direct Deflection Method. Two condensers may be compared as to their capacity, if first one and then the other is charged by a cell B of known e. m. f., and then discharged through a ballistic galvanometer G, Fig. 41. If the deflection with the standard of capacity C is D_1, and that with the unknown of capacity X is d_2 then

$$X = C\frac{d_2}{d_1}$$

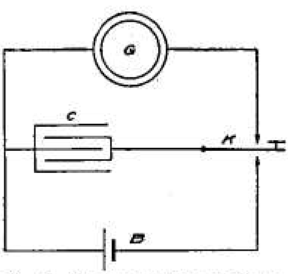

Fig. 41. Diagram for Direct Deflection Method.

A charge and discharge key K, Fig. 42, connects the condenser first to the battery and then to the galvanometer.

This method is convenient, but the accuracy of the results depends on the accuracy with which the throw of the galvanometer can be read. The accuracy is not much better than 1% even if neither