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SOME OBSERVATIONS UPON THE ACTION OF COHERERS WHEN SUBJECTED TO DIRECT ELECTROMOTIVE FORCE.

BY FRANK F. ALMY.

Most of the earlier quantitative work with coherers seemed to indicate that the coherer was uncertain or indefinite in its action. Some of the more recent work has, however, shown more definite and consistent results.

The measurements of Guthe and Trowbridge* on simple coherers subjected to sudden, direct electromotive force tend to show that the current through the coherer increases with the electromotive force in such a way that it would be represented graphically (using e and i as co-ordinates), by a smooth curve which in the limit becomes tangent to a line e = constant. The curves representing the results of their experiments are without abrupt change of curvature.

On the other hand Kinsley†, subjecting a filing coherer to a continuously varied electromotive force finds "that the resistance remains unchanged, as the potential difference is increased until a certain value is reached, when the resistance suddenly falls."

In August, 1901, I undertook some measurements upon the behavior of coherers, subjected to a continuously varied electromotive force. The E. M. F. was obtained by a simple potentiometer (Plate XIV), by means of which it could be varied continuously from zero to any desired value. An ammeter was placed in series with the coherer and a voltmeter in shunt across its terminals. The current flowing

*Phys. Rev. 11, p. 22.
†Phys. Rev. 12, p. 177.

through the coherer and the potential difference between its terminals were read directly.

For the determination of the behavior under the smallest E. M. F.'s a high resistance, four coil Kelvin galvanometer was used as voltmeter and a similar low resistance instrument as ammeter. For larger E. M. F.'s these were replaced in turn by milli voltmeter and millammeter; voltmeter and ammeter. This range of instruments indicates the range over which the investigation extended.

It was my fortune to have the use of one of the filing coherers used by Kinsley in his investigation; a coherer with fixed silver electrodes, with silver filings slightly coated with silver sulphide. The amount of filings in the gap between the electrodes was capable of adjustment. On measuring the current flowing as the E. M. F. was continuously increased, the current was found to increase in such a way as to be represented graphically by a smooth curve. The relation between the E. M. F. and the current depends upon the initial conditions, viz: the amount of filings between the terminals and the pressure upon them. The several curves seem to be related in such a way as to be expressed by the equation.

$$i = af(e) \quad - - - - \quad (1).$$

in which $i =$ current; $e \equiv$ E. M. F.

$a =$ a variable parameter, depending upon the initial conditions.

Guthe and Trowbridge give for their results:

$$f(e) = \log (1 - e / E)$$

when $E =$ the maximum potential difference that can be sustained between the terminals of the coherer.

Measurements were made upon a simpler coherer, consisting of a single contact between $\frac{1}{8}$ inch steel bicycle balls supported in a horizontal glass tube of slightly larger internal diameter. The balls were carried by spiral springs, one of which could be moved along the tube by a micrometer screw, in order to vary the pressure at the contact. The coherer was carried on an insulating base. This was floated in a vessel of mercury which in turn was floated in a second vessel of mercury. Connections were made with the coherer through wires supported independently, dipping one into a mercury cup on the base of the coherer, the second into the vessel of mercury in which the coherer floated, and into which dipped a wire from one terminal of the coherer. The whole apparatus was supported on a stone shelf. The measurements resulted in a family of curves similar to those obtained for the filing coherer, the individual curve depending upon the initial condition of contact. It would appear that the curves given by the measurements of Guthe and Trowbridge, and those which would represent the behavior of the coherer as described by Kinsley are but widely separated curves of the same family. For, using the filing coherer with a very few filings in a very loose contact, the results conform to those described by Kinsley, while with a large number of filings more closely packed, there is very slight variation of resistance with increased electromotive force. Between these two extreme conditions, results which conform to the curves of Guthe and Trowbridge are easily obtained.

This conclusion is further confirmed by the work of Bose* and Eccles†, that has appeared since the above measurements were made.

If instead of representing the behavior of the coherer graphically in terms of current and E. M. F., we represent the conductivity (reciprocal of resistance) of the coherer as a function of the current flowing, the curve becomes a straight line. *A linear relation exists between the conductivity of the coherer and the maximum current that has passed through it.* This is expressed by the equasion

$$C = C_0 + Ei \qquad \ldots (2).$$

where C = conductivity of coherer.

C_0 = constant depending on initial conditions (initial conductivity).

i = Maximum current that has passed through the coherer.

E = constant — corresponding to the maximum E. M. F. that the coherer can sustain.

From the series of simultaneous readings of voltmeter and ammeter the resistance of the coherer was calculated:

*Electrician, August 30, 1901.

†Electrician, August, 1901.

from that its conductivity was determined. In all cases, except for the initial part of the curve, the conductivity is a linear function of the current. In the initial part of any curve the scale readings of voltmeter and ammeter, beginning at approximately zero, were small, and the probable error in them and in the conductivity determined from them is correspondingly large, and consequently the values for this part cf the curve are somewhat indeterminate. This remark applies equally to the curves determined when the E.M.F. and current were of the order of magnitude measured by the galvanometers or by the voltmeters and ammeters. I have considered in the same way the results of Guthe and Trowbridge, Bose, and Eccles, and find the same relation to exist between the conductivity and current, except in the results of Eccles. In that case it is not certain that the resistance obtained from his tabulated values of E.M.F. and current is the resistance of the coherer alone. The departure from the law is such as to indicate that this is not the case.

It is interesting to note that the conductivity of dielectrics (parofine and guta percha) as deduced from the measurements of Leich* increases with the current flowing through them in such a way as to be represented by a straight line. Also that Ayrton and Perry† found the potential difference between the two carbons of an arc lamp was independent of the current strength provided the distance between the carbons was kept constant, or in other words, the apparent conductivity of the arc varies directly as the current. Shaw‡ has shown that after the electrical coherence or fall of resistance there is cohesion.

The resistance does not increase again after the current ceases to flow, unless the coherer is subjected to stress. The resistance after lowering is not affected by a current smaller than that which produced the lowering.

All these results seem in harmony with the theory of the coherer as advanced by Guthe and Trowbridge, that "as the current flows, ions from the positive electrode

* Wied. Ann. 66, p. 1107.
† Phil. Mag. May, 1883
‡ Phil. Mag. Mar., 1901.

break through the film, forming metallic contact, thus reducing the resistance," and that this takes place until a bridge of metallic particles is formed of such a cross section as to have a maximum carrying capacity equal to the current impressed.

Lodge* considers coherence to be of the nature of a welding together of the surfaces, and has been interpreted by later observers as considering the fall of potential due to the formation of a metallic bridge between the particles, "especially if the electric stimulus acted in any way as a flux by reducing the infinitesimal tarnish of oxide or other compound which must be supposed normally to cover them." It would seem that this conception might be possible if one considered the fluxing to be electrolytic.

*Phil. Mag. 37, p. 94; Electrician, 40, p. 87.