

Liquid Coherers and Mobile Conductors

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I have to express my thanks to Prof. Ebert of Kiel, in whose laboratory and under whose kind direction the experiments were carried out of which these observations form part.

Queen's College, Belfast,
27th February, 1897.

VI. *Liquid Coherers and Mobile Conductors.*

By ROLLO APPEYARD*.

IN a communication† made three years ago to the Physical Society, I described some experiments illustrating the change in electrical resistance of certain complex bodies under the influence of oscillatory discharges. All the substances dealt with were solids; and the coherence was invisible. The change of condition had therefore to be demonstrated either by measuring the resistance before and after discharge, or by connecting the coherers permanently in series with a battery and galvanometer.

The three experiments now brought before you have regard to "coherers" formed of liquid dielectrics, and mobile conductors. By choosing a transparent dielectric and an opaque conducting substance, it is possible to examine the process of coherence by direct observation. But it may be well to premise that the similarity of *results* obtained with solid and liquid "coherers," respectively, in no way proves a similarity of *process*. The two sets of phenomena are probably related, but are not necessarily identical. The term "dielectric" is here to be understood as signifying merely a substance of low conductivity.

Experiment 1.—A glass tube about eighteen inches long, and half-an-inch wide, is sealed at one end and corked at the other. Platinum electrodes are inserted at each end. The tube is nearly filled with about equal volumes of paraffin-oil and mercury. If it is laid upon a flat table and shaken, horizontally, for a few minutes, the mercury breaks up into

* Read March 26, 1897.

† "Dielectrics," Phil. Mag. xxxviii. p. 396 (1894); Proc. Physical Society, xiii. p. 155 (1895).

small spheroids; and, by a little manipulation, these can be disposed as a chain of particles lying evenly between the platinum electrodes. The resistance of the chain of mercury spheroids, measured under these conditions, is several megohms.

If we now connect the electrodes to a battery of about two hundred volts, the whole regime is suddenly altered. At the moment of applying the current, the spheroids of mercury, within the tube of oil, are visibly impelled, as though a mechanical tap had been administered to the glass; and, almost simultaneously, they coalesce into large globules. The resistance is now represented by a few ohms.

Exactly the same result can be brought about by supporting the tube near a Hertz oscillator; or, still more simply, by passing a spark into one or other, or both, of the electrodes. In order to retard the spontaneous coherence of the mercury, resulting from mutual pressure of the spheroids, it is well to keep the tube horizontal. If, however, it is desired quickly to convert a body of mercury from the subdivided to the ordinary state, sparks may be passed into the tube while it is more or less vertical. The running-together of subdivided mercury is more leisurely to be observed with large globules. These form separate, elongated, conductors. The way in which they unite will be referred to in describing Experiment 3.

Experiment 2.—A glass tube, similar to the first, but somewhat wider, is nearly filled with a mixture of paraffin-oil and water, and vigorously shaken. I propose to call this a “rain” tube. If it is kept at rest, the oil, in the common course of events, floats to the top in a few minutes. The “rain” tube, however, shows that the separation, especially towards the final stage, is accelerated by the passage of a spark, or by a direct current from a battery of about a thousand volts. If the conditions are right, the water particles suspended in the oil cohere, at the moment of electrification, to form larger drops. The frictional resistance to falling is thereby diminished, and the water is consequently precipitated in and through the oil. It may sometimes be seen descending in a rapid succession of globules, precisely as large rain-drops are precipitated after thunder. About equal parts of oil and water is a good

proportion. The containing vessel may be either a tube or a flask; it should not be more than three-quarters full of liquid. This free space facilitates the mixing when the tube or flask is shaken. The phenomenon is rendered much more striking by colouring the oil with alkanet-root. I have to thank Prof. McLeod for suggesting this pigment.

Experiment 3.—The behaviour of a mobile conductor, when electrified in a partially conducting liquid, is readily examined by pouring a little mercury into a flat photographic dish containing a stratum of paraffin-oil and water. The presence of the oil is necessary to prevent the mercury from running together too freely of its own accord. A battery of from, say, one volt to two hundred is required, and a pair of wires to dip into the dish. A reversing-key, such as is used for cable transmission, may be included in the circuit.

Suppose we begin with a large globule of mercury in each of any pair of corners of the photographic dish, several inches apart; and let the globules be connected one to each pole of the battery, by means of the dipping wires. A momentary tap of the key causes instantaneous deformation of the mercury in each corner, especially of that connected to the negative pole; and there is evident attraction between the globules. Sometimes the mercury gets into a lethargic condition; but it can always be roused by mechanical agitation of the surface. Now let the current be kept on for a few seconds; the negative globule sends forth a tentacle towards the positive globule, the length of the tentacle depending upon the current and the distance between the globules. Under favourable circumstances it may extend from corner to corner, and thus establish contact; or *fissure* may occur, the tentacle breaking into spheroids; and these spheroids may cross over between the globules. This is the order of things usually to be observed, but the action is sometimes erratic.

Let us now bring back the scattered globules of mercury to their respective corners, and distribute a few isolated spheroids in the interspace. In addition to the effects previously noticed at the terminal globules, we now see that, when the current is applied, each intermediate spheroid extends a "finger" towards the positive globule. This is the process of mobile coherence; the short "fingers," or long

"tentacles," form links between consecutive spheroids, and finally a complete conducting circuit is established.

By successive applications of the current, any elongated bodies of mercury between the terminal globules can be made to creep along like caterpillars; the successive forward motions of the tentacle, or tail, cause a corresponding retrogression of the globule as a whole.

Any small spheroids scattered about the dish may be urged in a direction depending upon the direction of the successive current impulses; and a "finger" will always appear on the side towards the positive electrode. So that by choosing a convenient stray spheroid, and operating a battery-reverser as a transmitting-key, a telegraphic receiver is improvised from no other apparatus than a drop of mercury and a little oil. By some such means the awakening genius of primitive man may have contrived all the subtle machinery of a telegraph-instrument upon the smooth surface of an oyster-shell.

DISCUSSION.

Prof. RAMSAY said he had once attempted to facilitate churning by the application of 8 or 9 volts to some milk. He thought the cream came a little faster, but it turned sour very quickly.

Prof. FITZGERALD thought that the effects observed in experiment 3 were the result of current, and not of electrostatic changes; and he would like to know the value of the actual current used. There was no doubt that the motions were due to variations in capillarity.

Mr. SHELFORD BIDWELL asked how the mercury was formed into spheroids in the tube in experiment 1.

Mr. APPLEYARD, in replying to Prof. Fitzgerald, said it was not easy to define the circuit, as the terminal-globules were rather capricious, but he would try and measure the current in some particular case. The mercury-tube in experiment 1 was shaken in a horizontal plane; the operation took about ten minutes. Equal volumes of mercury and oil was a good proportion. One quarter of the length of the tube should be left as an air-space.
