"The Sparking Distance between Electrically Charged Surfaces.—Preliminary Note." By P. E. SHAW, B.A., D.Sc. Communicated by Professor J. H. POYNTING, F.R.S. Received March 22,—Read April 28, 1904.

Lord Kelvin* first made systematic measurement of the relation between potential difference and sparking distance. He noticed that these factors do not vary in proportion and he surmised that this might be due to "the air near dense bodies being condensed and so becoming a better insulator."

Later G. A. Liebig† published results bringing voltages used to as low as 800, the discharge distance being 67 micra. Both the above observers used frictional machines to produce E.M.F. and worked in electrostatic units.

R. F. Earhart‡ made a new departure, using a continuous current from accumulators, and obtained consecutive results with voltages from 1000 to 38; the corresponding sparking distances, ranging from 100 μ to $\frac{1}{4}$ μ, were measured by Michelson's interferometer.

One very interesting result of his research was that the potential gradient, dv/dx, suddenly changes when the sparking distance is about 2 μ (see fig. 2); for greater distances dv/dx is 7 (volts per micron) whereas for less distances it is 200. Thus a distinct "knee" is formed in the curve connecting V and x. I have suggested an explanation of this.§

It has been shown that the thickness of the condensed water film on solid surfaces at ordinary pressure and temperature is about 0·8 μ. If two surfaces approach one another to a distance of 2 μ then, deducting 0·8 μ for the film on each surface, we have an air distance left of only 0·4 μ, which would be easily bridged by small vibrations of the surfaces, and the bridge would be stable on account of capillarity. Thus any discharge would take place through the water film and not through air. The film on recently cleaned metal would be very pure and would have a dielectric strength greater than air (from the numbers quoted it appears to be thirty times as great), hence the sudden rise in dv/dx.

Mr. Earhart tried the effect of increasing and decreasing the atmospheric pressure. Increase in pressure causes small increase in dv/dx below the "knee" and large increase above the "knee"; but what is more important to notice is that increase in pressure causes the "knee" point to move up the curve corresponding to greater sparking distance. These last results support the theory

* Thomson, 'Roy. Soc. Proc.,' 1860.

† 'Liebig, 'Phil. Mag.,' vol. 24, 1887.

‡ Earhart, 'Phil. Mag.,' vol. 1, 1901.

§ Parks, 'Phys. Soc. Proc.,' Discussion, p. 418, 1903.

put forward, for the film would increase and decrease in thickness directly with pressure.

W. R. Carr* made similar investigations, but as he worked with reduced pressures and his discharge distance was never less than 1 mm., whereas mine is never greater than 1 μ, our work does not overlap.

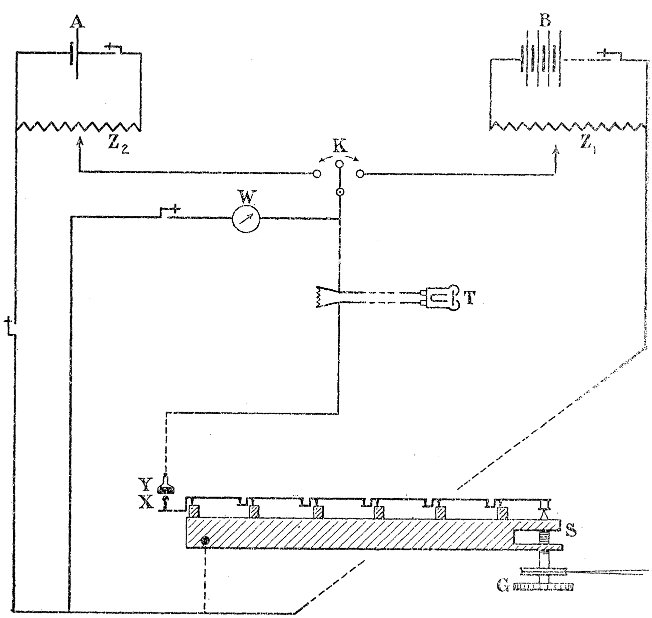
Suppose two surfaces having a constant potential difference (V) approach one another, the tension between the charged surfaces at last breaks down the medium when the distance apart is x. The space between the contact surfaces may be occupied by one or more media, each medium having dielectric strength, either constant or varying from point to point. Two cases concern us—

1. One medium, uniform in dielectric strength; we can express the critical potential in terms of potential gradient. The curve between V and x is a straight line to the origin.

2. Two or more media uniform in dielectric strength. The curve is a succession of straight lines.

Referring to fig. 2 it will be seen that Earhart's curve is composed of two *straight* portions. Hence on the above hypothesis the water film has a constant dielectric strength and so has the air outside, the strength of the former being about thirty times that of the latter.

Fig. 1.



* 'Phil. Trans.' vol. 201, 1903.

I have investigated this subject by means of the electric micrometer,* which is specially well adapted for the purpose, as it measures by the principle of electric touch. Briefly expressed, it has a fine micrometer screw S (fig. 1) with a graduated wheel G; and a system of six levers is arranged to minify the movement of the screw point, thus 1 μ movement of the screw-head becomes 1 $\mu\mu$ or less of the point X. A fixed surface Y is arranged near the adjustable one X, and when X and Y touch a circuit is completed as shown through the telephone T. To find the position of contact the observer works the screw S, watches the wheel G, and listens at T. The spark gap is across XY. A battery B capable of giving 200 volts has a potential divider Z_1, which enables us to apply to XY any required voltage, which is read on the voltmeter W. A key K enables us to use either the large voltage from B on a small voltage ($\frac{1}{20}$ volt) from A, also provided with a potential divider Z_2. To make an observation apply the small voltage from A, ascertain the position of contact by G and separate the contacts XY. Now apply the large voltage from B and slowly bring the contacts together until discharge occurs, as observed in the shunted telephone. G is again read. The results follow (p. 341).

The table shows Earhart's results with mine. There are some points of interest:—

1. The last two columns show potential gradients. There does not appear to be any change in gradient nearer the origin than 2 μ, hence we infer that there is no inner film or change in dielectric strength.

2. In working the electric micrometer I commonly use a potential difference across the contacts of $\frac{1}{20}$th volt.; it might be supposed that this voltage would produce irregular discharge and make the readings of the instrument uncertain. The table shows that the sparking distance would be about $\frac{1}{2}$ $\mu\mu$. So that even if there were a large percentage error in this distance the errors in measurement would be insignificant.

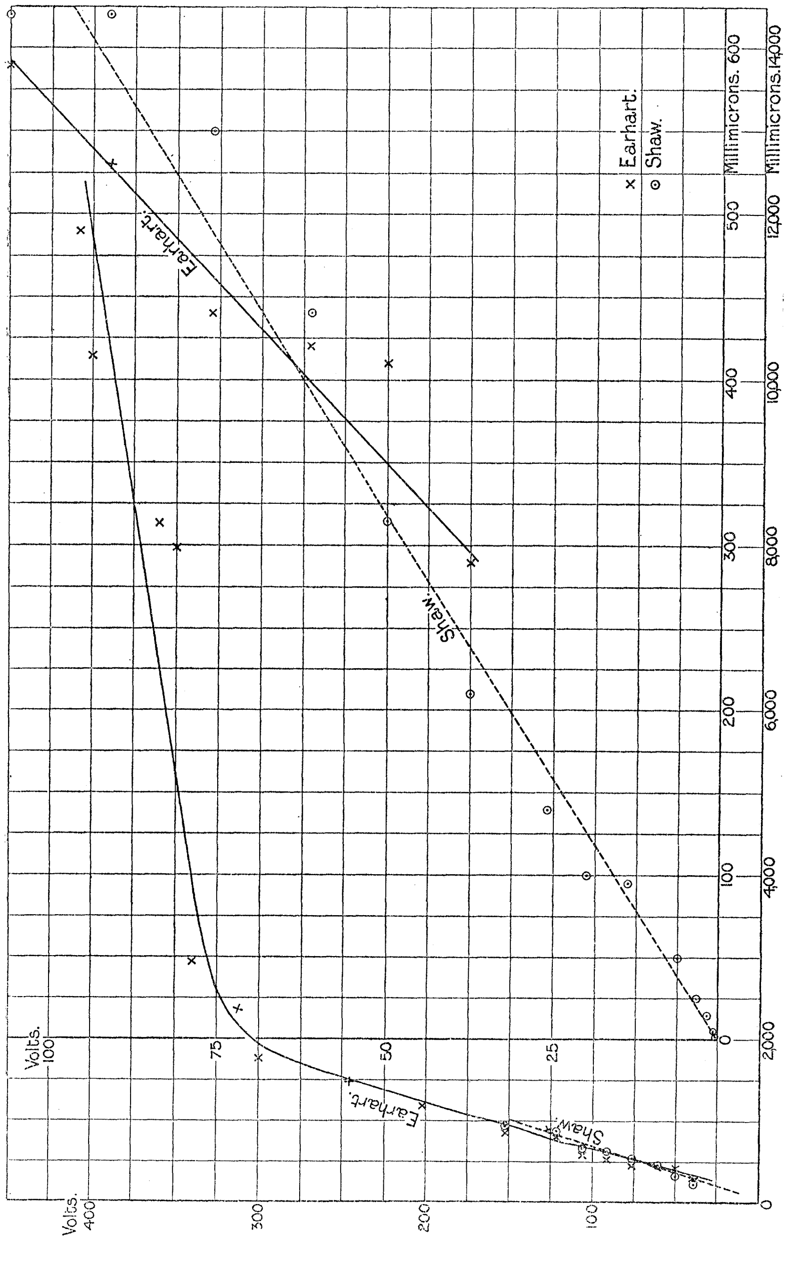
The curves are shown in fig. 2. The curves on the left side indicate good agreement between the two observers, where they overlap.

We should expect more regular results when there is a pure liquid between the surfaces than when there is an air gap; for dust particles which would interpose in the air could not break into the liquid. Earhart's results show great difference in regularity on the two sides of the "knee." The curves on the right are on an open scale to show my results better.

The potential gradient for Earhart's results is 200—for mine 150, the curves crossing one another for voltage 60.

* For an account of this instrument, see Shaw, 'Phil. Mag.,' December, 1900; March, 1901; 'Electrician,' February, 1901.

Fig. 2.


× Earhart.
⊙ Shaw.
Earhart.
Shaw.
Earhart.
Shaw
Millimicrons. 600
Millimicrons. 14,000
500
12,000
400
10,000
300
8,000
200
6,000
100
4,000
0
2,000
0
Volts.
100
75
50
25
Volts.
400
300
200
100

V (volts).	Millimicrons.		Volts per micron.	
	Earhart.	Shaw.	Earhart.	Shaw.
408	11800	..	7	
400	10300	..	,,	
360	8260	..	,,	
350	7960			
344 > 336	2950			
312	2360			
300	1770		200	
240 > 250	1480	..	,,	
202	1180	..	,,	
152	880	950	,,	150
121	800	860	,,	,,
106	590	700 650 > 670	,,	,,
91	530	600 650 > 620	,,	,,
76	440	550	,,	,,
61	420	440	,,	,,
50	410	300 330 > 315	,,	,,
38	290	210	,,	,,
26	..	140	..	,,
20	..	100	..	,,
13·5	..	95	..	,,
6	..	50	..	,,
3	..	25	..	,,
1·5	..	15	..	,,
0·6	..	5	..	,,
0·5	..	5 4 > 4·5	..	,,
0·2	..	2 3 > 2·5	..	,,

Details.

Previous observers have been careful to have plain or spherical surfaces opposed so that the conditions of discharge should be definite. But when the discharge distance is, as in this case, always less than a micron and sometimes only a few millimicrons, the form given to the surface is of little importance, for in a polished surface there will exist irregularities on each surface of the order of the distance between the surfaces. In that case discharge will occur from a point on one surface to the nearest point on the other surface. I generally used a bead of iridio-platinum (1 mm. diameter), and a plane of iridio-platinum, both highly polished.

In using high voltage the surface must be repolished after every discharge, but for small voltage (less than 5) the surface will not

be so much shattered and can be used two or three times before repolishing.

I made special tests with a copper bead and copper plate, but there was no change in results. Also using a copper point and copper plane the gradient came out about half as much as indicated in the table above. Again, when using a bead and disc, it is found to be immaterial which is positive and which negative, so that for small distances there does not appear to be a different positive and negative tension as was found by Faraday for large distances.

I hope to continue the research, varying the conditions. My best thanks are due to the Royal Society for grants in aid of research extending over the last three years.

I wish also to express my great obligation to Professor W. H. Heaton for granting me every facility in my investigation.

"Further Note on some Additional Points in Connection with Chloroformed Calf Vaccine." By Alan B. Green, M.A., M.D. (Cantab.). Communicated by Dr. W. H. Power, C.B., F.R.S. Received April 19,—Read May 5, 1904.

(From the Government Lymph Laboratories.)

Since April, 1903, the date of my preliminary note* on this subject, the preparation of calf vaccine by the chloroform process has been carried on in at these laboratories and a large number of vaccines have now been treated by this method. These lymphs have been freed from their non-sporebearing extraneous bacteria within a period ranging between 1 and 8 hours after their collection from the calf, and have, subject to the usual tests, been issued for general vaccination purposes about 2 weeks after collection. Their use has resulted in high "case" and "insertion" success.

The following points in connection with these vaccines have been investigated.

The Effect of Temperature in the Elimination of Extraneous Micro-organisms from Crude Calf Vaccine by the Chloroform Process.

It has been ascertained that the temperature at which vaccine emulsion is subjected to the chloroform process determines largely the rate at which the extraneous bacteria of that emulsion are eliminated. This has been shown in two ways.

* 'Roy. Soc. Proc.,' 1903.