SPARKING DISTANCES BETWEEN PLATES FOR SMALL DISTANCES.

By R. F. Earhart.

It is desired in this article to supplement a series of measurements made some two years ago, on the sparking distances between plates for small distances. (*Phil. Mag.*, Jan., 1901).

In the previous determinations, there was used an e.m.f. obtained from a bank of storage cells. In the present case measurements have been made in which the e.m.f.'s are periodic in character. Some measurements have been made on the effect of introducing capacity in circuit. The periodic e.m.f.'s here considered were taken from a transformer connected with the city lighting mains, and having a 60-cycle period. Dependence on station regulation is perhaps unfortunate but by proper choice of hours for experimentation little difficulty was encountered on account of fluctuation in potential. The conditions to be fulfilled in this problem are: (1) To measure a small distance accurately, (2) to measure a potential difference accurately.

In order to fulfill the first condition, recourse was had to an interferometer; measurements of distance being made in terms of wave-lengths of sodium light. The method of accomplishing this will be readily understood by consulting Fig 1. The electrical conditions require that one surface should be spherical. In this case a bicycle ball 2.52 cm. in diameter was mounted on a rigid support and insulated therefrom. The opposite surface (D') was mounted in a similar manner and attached to the movable carriage of an interferometer (C) which bears the mirror (M). The surface (D') could then be brought in contact with the spherical surface (D) and separated, the distance of separation being readily interpreted by the number of fringes passing the field during the course of separation. The method of determining contact between the surfaces was to include a galvanometer and a small e.m.f. (about .02 volt) and determine the point of contact electrically. This point can be easily determined to within ½ a fringe, *i. e.*, ¼ λ or approximately .15 micra. No effort was made to determine distances more accurately; for this lies well within the limit of accuracy of the e.m.f. determinations.

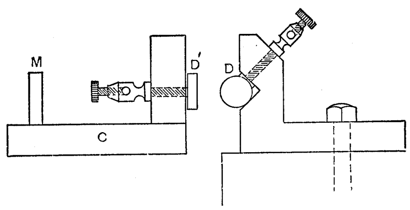

Fig. 1.

Correction has not been made for the sphericity of one surface for the distances measured are of the order of a wave-length of light, whence a radius of curvature of 1.26 cm. is relatively large.

The surfaces used were ground, polished and, in some cases, nickel-plated, approximating optical surfaces as nearly as possible. It is necessary that optical surfaces be approximated in order to obtain consistent readings.

The e.m.f.'s were obtained from a Westinghouse transformer 2000–100 volts, used as a step-up transformer. By suitable connections with the ordinary house mains an e.m.f. of 2,000 volts was available. This 2,000-volt current was passed through a bank of 20 lamps connected in series. These were mounted on a board, the terminals of each lamp dipping into a mercury cup as indicated in Fig. 2. It is thus possible to obtain a considerable range in potential difference by utilizing the drop in potential along the series. The P.D. between the terminals of each lamp, approximately of 100 volts, may be reduced by grouping lamps in parallels. An auxiliary board with suitable connections (not shown in figure) was used for this purpose; so that e.m.f.'s ranging from 10 to 2,000 volts in steps of 10 volts were available. These e.m.f.'s were measured by a Kelvin milleampère balance provided with suitable non-inductive resistances to reduce the flow through the balance below the safety limit.

The method of procedure, then, was to separate the plates a given distance and establish connection with the busbars (F, F)

Fig. 2. The P.D. between the busbars could then be varied by connections between the bars and the mercury terminals of the lamps.

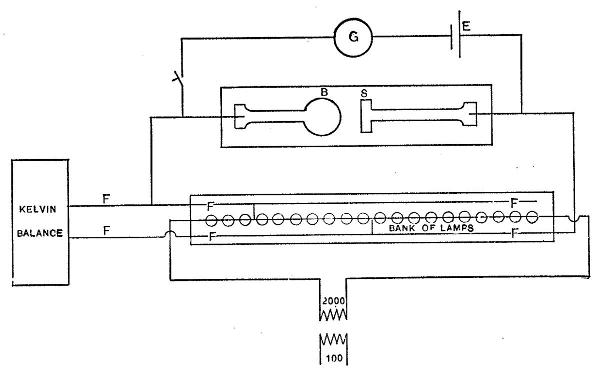

Fig. 2.

Since the Kelvin balance takes an appreciable current and is shunted across the lamps, this serves to reduce the potential between the lamp terminals, hence it is necessary to keep the balance circuit closed when applying an e.m.f. There being no inductive resistance in the circuit or a negligibly small one, the e.m.f.'s can be readily computed from the balance readings. In considering some of the results where capacity was included in the circuit some question as to the effect of the balance on the results arose. A set of Kelvin electrostatic voltmeters being available, these were connected across the busbars and measurements obtained almost identical with the balance both when the capacity was in the circuit and when the capacity was negligibly small. This instrument, like the balance, gives the square root of mean square values for a sine curve e.m.f.

Results.—A series of readings wherein nickel-plated surfaces were used are given in Table I. and represented graphically in Plate I. Readings given are those of maximum potential and obtained from square root of mean square values as given by the balance. This curve is almost identical with that obtained from static discharge, hence we conclude that a given potential is required to cause a spark to pass between such surfaces and that the character of the potential difference, whether static or perodic is unessential.

Nickel Surface.

Distance in Wave-lengths.	Potential in Volts.		Distance in Wave-lengths.	Potential in Volts.	
	1st Spark.	2d Spark.		1st Spark.	2d Spark.
1	72		15		515
1	120		20	392	520
1.5	128		25	403	510
2.0	137		30	403	598
2.5	242		35	414	573
2.5	250		35	441	555
3	256		40	547	656
3	270		45	555	671
3	248		50	590	743
4	337		55	585	750
5	350		75	700	820
5	300		85	750	865
6	321		100	785	865
6	307		100	786	1030
8	320		100	700	940
10	345		100	910	1070
10	347		150	974	1200
10	330		200	1100	1250
12	300	364			
15	371	500			

As with the static P.D., so in this case, there seems to be a change in the law at a distance of about three wave-lengths. At distances less than this the P. D. required to cause a spark to pass seems proportional directly to the distance of separation but above this point the relation between potential and distance follows a different law.

I have distinguished between what is termed the first and second spark. When a sufficient potential is established between the disk and ball a spark will pass, if now the e.m.f. be withdrawn the same potential will not cause the spark to leap the air gap a second time. It seemed possible that the discharge had torn off some of the plating, thus increasing the distance. To determining whether or not this was the case I reversed the motion of the interferometer carriage after the first discharge and counted the number of fringes passing the field during tne retrograde motion until contact was made. In the case of the plated surfaces and for a large number of measurements I found the point of contact to be unchanged.

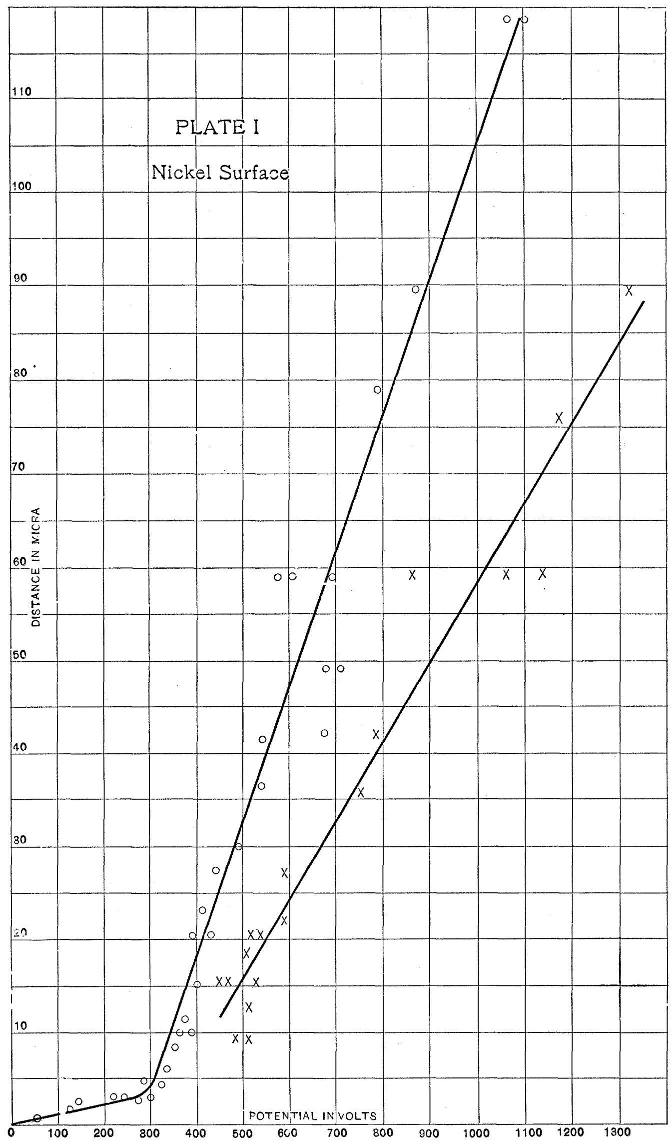
PLATE I
Nickel Surface
DISTANCE IN MICRA
POTENTIAL IN VOLTS
110
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300

Fig. 3.

Steel Surface.

Distance in Wave-lengths.	Potential in Volts.		
	Capacity None.	Capacity 0.2 Microfarad.	Capacity 0.4 Microfarad.
5	90	125	135
8	225	200	155
10	255	230	165
12		290	234
15	298	286	303
20	305	320	330
25			392
30	345	360	410
40	410	420	530
50	496	490	584
60	520	545	659
75	580	600	728
100	670	825	872
125	790		
150	840		

A microscopic examination of the surfaces afforded a possible explanation. The nickel film seemed pierced by the discharge, the spark apparently seeking the ball below the nickel film. This discharge point had the appearance of a crater more or less regular in form, moreover the crater and adjacent nickel were coated with a film of iron oxide, probably carried out by the discharge. There were small projections at the edge of the crater but all fused and rounded down. Quite possibly, although the surface appeared initially smooth, there were minute roughened projections which the fusion by the discharge would round down. This, together with the slight coating of oxide, would explain the fact that a higher potential was required for second discharge. A number of early readings appeared to indicate some regularity for the second P.D. as defined above but a large number of readings proved this a fallacy. The readings given for first spark are shown in Plate I. by circles (o), for second spark by crosses (x). The potential required for second spark seems dependent on the character of the crater formed by the initial spark.

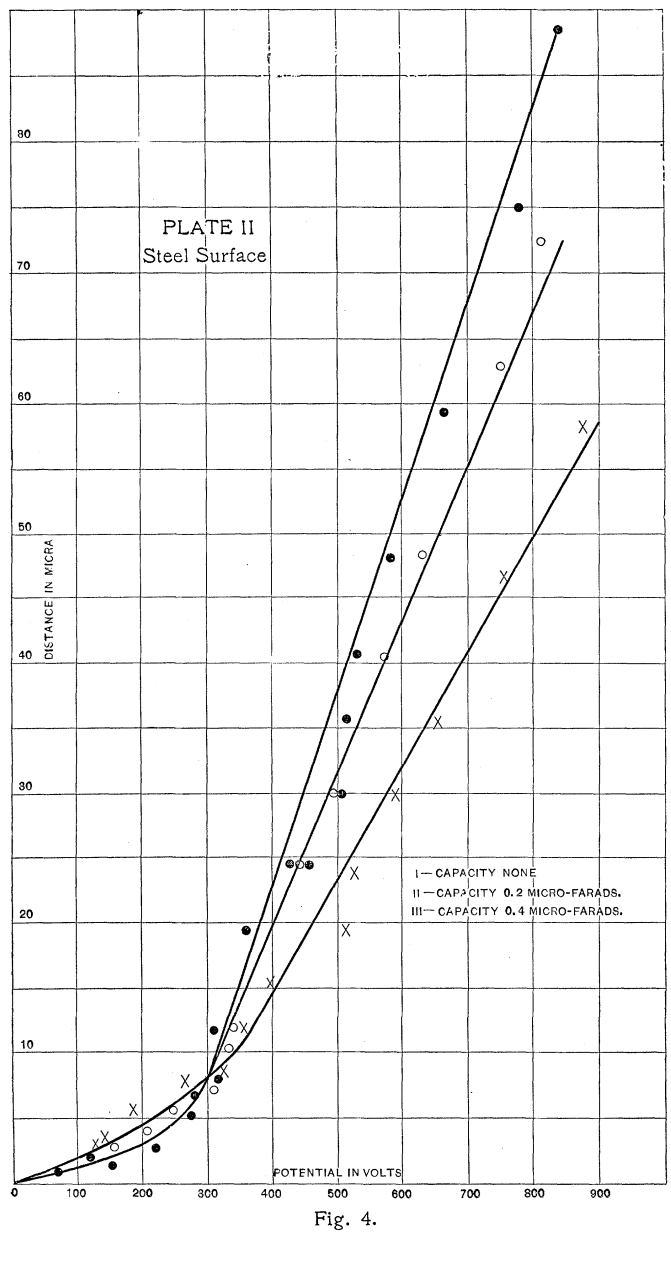
PLATE II
Steel Surface
DISTANCE IN MICRA
POTENTIAL IN VOLTS
I — CAPACITY NONE
II — CAPACITY 0.2 MICRO-FARADS.
III — CAPACITY 0.4 MICRO-FARADS.
0
10
20
30
40
50
60
70
80
100
200
300
400
500
600
700
800
900

Fig. 4.

In using steel surfaces, the general character of the curve agrees with the curve for nickel surface. A bicycle ball and disk ground and polished but not burnished were used. I was unable to obtain as satisfactory a surface in this case which probably accounts for the slightly lower potential required for a given distance.

In the case of no capacity curve, it was found that up to about 100 wave-lengths the potential for second spark was the same as for the first. Up to 15 wave-lengths the surfaces fused together on first discharge. Several measurements were made for a distance of 50 wave-lengths. It was found on pushing back the disk that the distance to contact had decreased from 10 to 12 wave-lengths, so that although the same potential as before was required the air gap was less. After a distance of 100 wave-lengths was reached the potential required for second discharge was greater than for the first. The oxidation and rounding down of the surfaces will, I think, account satisfactorily for all of these things.

The curves given in Plate II. are for steel surfaces. Curve I. representing values obtained with no capacity in the circuit, Curve II. when a capacity of 0.2 microfarad is introduced and Curve III. for 0.4 microfarad. Some measurements were made with a capacity of 1.36 microfarads which give values similar to those of Curve III. This particular condenser broke down at the higher potentials and for the present I have no means of checking the values, hence they are not tabulated. They seem to indicate that a farther increase in the capacity will not modify the result materially.

The effect of capacity seems to round out the elbow of the curve as it were. Below this point introducing a capacity seems to diminish the potential required for discharge, while above a limiting point a higher potential than before is required. The individual readings from which the curves are plotted are given in Plate II. Curve I. is plotted from values represented by a dot (.), Curve II. by a circle (o) and Curve III. by a cross (×). These values form only a small part of the data obtained but are not selected values. They represent one continuous run of readings, the other values showing fair agreement with these.

During the early stages of the experiment rather elaborate precautions were taken to exclude dust and water vapor, but in repeating a series of measurements these were dispensed with. It was found that the presence of dust and water vapor affected the results to a very slight extent, if at all. Most of the readings given are those in which no precautions were taken to guard against either dust or vapor and are under the conditions which ordinarily prevail in a laboratory with regard to temperature, etc.

I wish to express my obligations to the authorities of Ryerson Laboratory of the University of Chicago for the use of an interferometer with which these measurements were made.

Rose Polytechnic Institute,
Terre Haute, Ind., June, 1902.