An Investigation of a Point Discharge in Magnetic and Electrostatic Fields.

By Oscar William Silvey.

A year ago the writer[1] presented at the meeting of the Indiana Academy of Science a report of an investigation of the electric point discharge in a magnetic field of 1,500 gausses. In this work it was found that the stream of air from the negative electrode was in no case deflected, and if the glow discharge existed between the points neither positive nor negative stream was deflected by a field of this strength.

The purpose of the present investigation was to repeat with a stronger magnetic field the work described in the previous report, to study the effect of an electrostatic field upon the path of the spark, and to determine if possible the nature and velocity of the particles composing the stream emitted from the points.

The apparatus used in this and the previous work was that constructed by Professor Foley and Mr. Haseman[2] for the investigation of interference fringes about a point discharge, air streams, and vapor streams. It consisted of a long wooden tube (Fig. 1), one part of which was made to telescope over the other part. This provided a means of separating the two parts for adjusting the points and magnet. Another portion (E, Figs. 1 and 3) containing a plate holder F was made to fit over the end. Black screens (Fig. 4) were placed at intervals throughout the tube so that no light would be reflected from the sides. The end of the tube was closed by a cap (C), which shut out all light except from a pinhole, as shown by Fig. 2. A circular disc with holes of various sizes provided a means of regulating the amount of light. A is a 90° arc light, the center of which is focused on the pinhole by means of the lens B.

Light was shut out of the tube by placing a piece of plack cardboard in front of the pinhole. When a photograph was to be taken, if the discharge was a glow or a brush, the slide S was drawn from over the plate, and after the tube had come to rest, the cardboard was removed until the

[1] Proceedings of the Indiana Academy of Science, 1909.

[2] Not yet published.

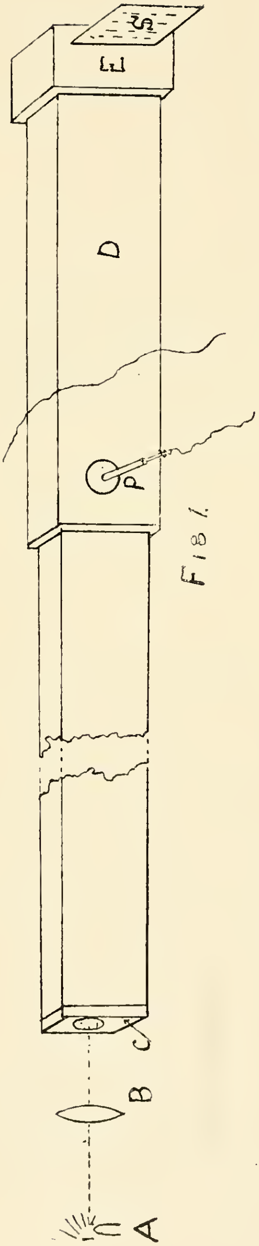


Fig. 1

plate was sufficiently exposed. In case of the spark discharge which fogged the plate if exposed too long, the cardboard was first removed and the exposure made by withdrawing the slide.

The magnet used was of the Faraday type (photographs, Figs. 7 and 8), with pole pieces $3\frac{1}{2}$ inches in diameter, and with a current of 22 amperes gave, midway between the pole pieces, when 49 mm. apart, a field strength of 6,400 gausses. Longitudinally through the cores and the pole pieces was a hole 2.54 cm. in diameter. If the holes were filled by placing in them an iron cylinder of the same material as the cores, and the air gap reduced to 1 mm., a field strength of 40,000 gausses for a current of 44 amperes could be produced. In most of the

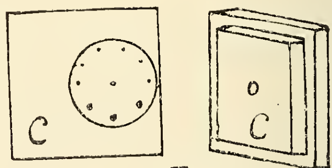


Fig. 2

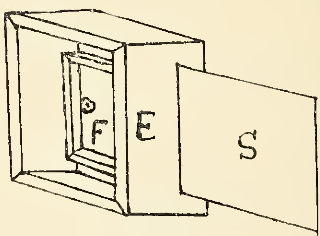


Fig. 3

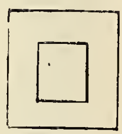


Fig. 4


Fig. 6


Fig. 5

following work the air gap was 49 mm. and the current 22 amperes. In order to obtain a photograph of the current which passed between the points transverse to the magnetic lines of force it was necessary for the

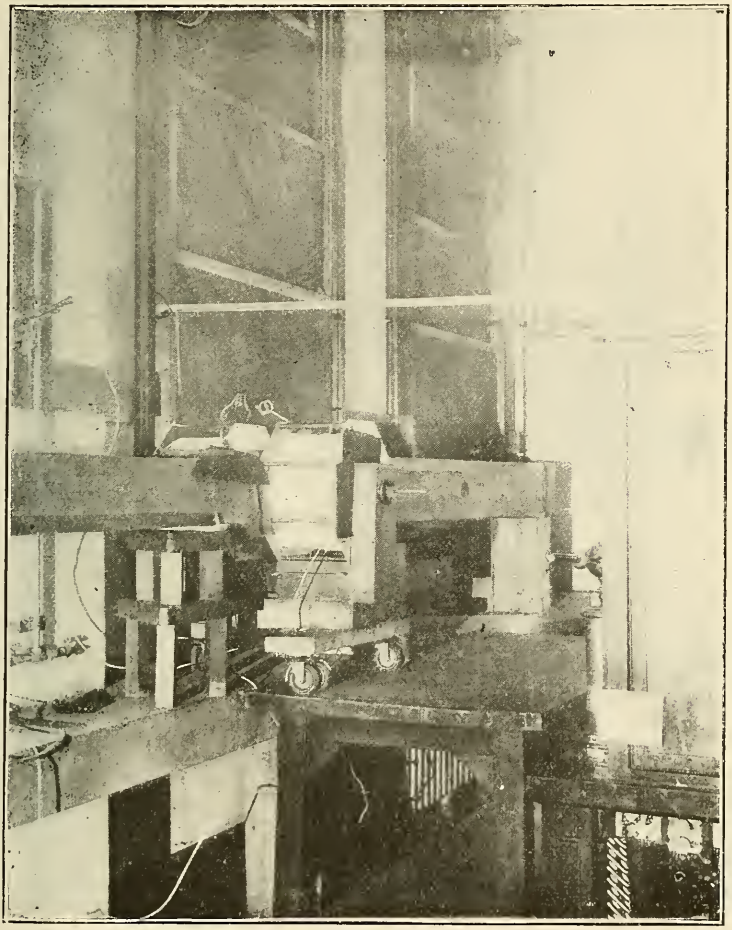


Fig. 7.

light from the pinhole to pass through the hollow cores of the magnet. This was accomplished by fitting the two portions of the tube against the magnet, as shown in photograph, Fig. 8. An auxiliary wooden tube 25 cm. square and 12.5 cm. long was placed between the coils of the magnet to shut out all light except from the pinhole, and to hold rigidly the insulating glass tubes, which firmly held the rods containing the points. An opening was cut in the upper side of this auxiliary tube and a suitable

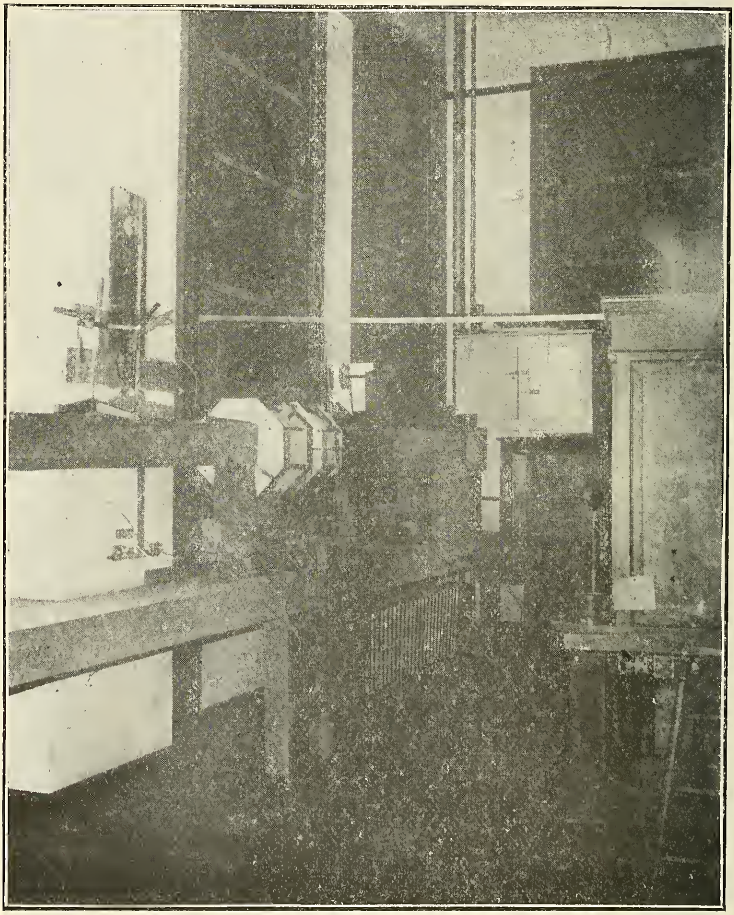


Fig. 8.

cap provided, so that one could easily open it to adjust the points, or to observe the nature of the discharge. The inside of all portions of the tube and the inside of the hollow cores were painted a dead black.

When a photograph of the discharge parallel with the lines of force was desired, the magnet was turned with its axis perpendicular to the axis of the tube, and the glass tubes, held in position by corks in the hollow cores, provided insulation for the rods holding the points. In this case also an auxiliary tube 12.5 cm. square and 1 meter long was placed between the coils and telescoped into the two portions of the longer tube which were too large to fit between the coils. This small tube had a circular hole in each of two sides to receive the pole pieces of the magnet, and another in the upper side similar to the one in the first auxiliary tube described.

In all cases the magnet was electrically connected to earth and the wires bearing the current were separated from the walls of the room and from the camera by means of glass tubing, when they were too near for the air to insulate them. All metal parts used in the magnetic field, such as screws in the auxiliary tubes, were of brass.

When studying the deflection of the discharge due to electrostatic deflection, the tube was used as shown in Fig. 1. Two brass plates 8 by 5 cm. were placed one above the other below the points. They were held in position by brass rods soldered perpendicularly to them at the center. The rods were firmly fitted into glass tubes which passed through the upper and lower sides of the tube. For part of the work the plates were connected electrically in multiple circuit with the points, while for the other part they were charged by means of a small Holtz machine. The points were charged by a four-mica plate Wagner electrostatic machine, from which the Leyden jars had been removed. Both the Wagner and the Holtz machines were run by electric motors with rheostats in circuit for varying the speed. Sixteen different speeds were possible with the Wagner, and eight with the Holtz machine.

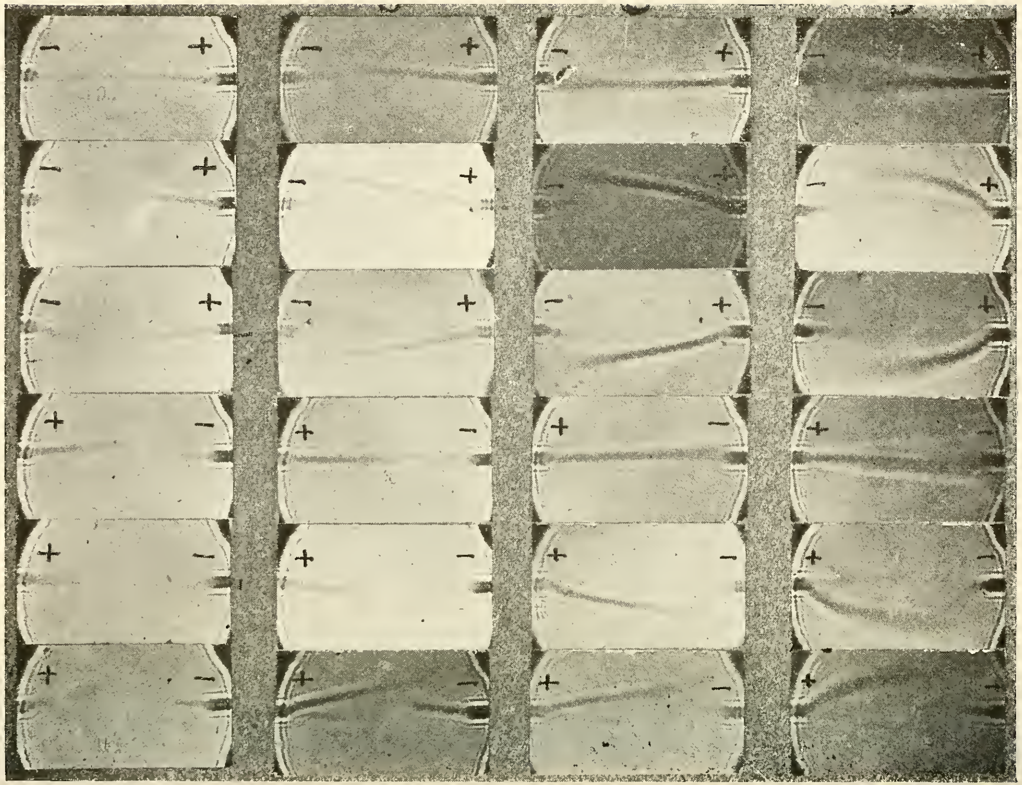
The points were made of brass pins 1.15 mm. in diameter and 4 cm. long. They were put in a lathe, sharply pointed by means of a carborundum stone, and made to slope 2.5 cm. from the end. They were soldered into the ends of brass rods 5.57 mm. in diameter.

TRANSVERSE MAGNETIC FIELD.

The apparatus was first adjusted with the points at right angles to the direction of the magnetic lines of force and the photographs of series A, B, C and D were taken.

Plate I. Transverse Magnetic Field.

No. 1.
No. 2.
No. 3.
No. 4.
No. 5.
No. 6.



A B. C. D

No. 1. Current 1st, No. 4. Current 2nd direction, magnetism (none).
No. 2. " " No. 5. " " " " 1st direction.
No. 3. " " No. 6. " " " " 2nd "

Series A is a glow discharge representing the lowest speed of the machine. (Nothing was visible between the points in the darkened tube. Each point showed a tiny bright speck.)

Series B is a brush discharge representing a higher speed. (A violet stream extended about 0.8 cm. from the positive point. The negative point showed only a bright speck.)

Series C is a visible spark discharge representing the lowest speed at which a visible spark is maintained. The spark was changed to brush when the magnet was excited.

Series D is a visible spark discharge representing the highest speed of the machine.

The six numbers of each series were taken in succession as rapidly as possible, it requiring 20 to 30 minutes to complete the series. In the photographs, the longer stream is the one from the positive terminal and the shorter one the stream from the negative electrode. If the positive stream is from right to left it is designated as the first direction; if from left to right as second direction. Nos. 1, 2, 3 then show current in the first direction, while Nos. 4, 5 and 6 show current in the second direction. If the magnet was excited so that the sense of the lines of force was from back to the front of the photograph (i. e., after correcting for the reversal in direction caused by printing from the plates), the magnetization is designated as first direction and those with the lines of force from front to back of the page are designated as magnetized in the second direction. Following then this plan, Nos. 2 and 5 show the current in a field of the first direction, while Nos. 3 and 6 show the current in a field of the second direction, and Nos. 1 and 4 show it when the magnet was not excited. It may be observed from the photographs that the streams in series A, B, C and D are deflected as if they were flexible conductors bearing a current in so far as direction of deflection is concerned, thus indicating that the stream is one of charged particles.

The magnetic field strength, measured by a bismuth spiral, was about 6,400 lines per sq. cm. in the region of the points. The points were 18.05 mm. apart. The potential of the points was the highest for series B and did not increase as the speed increased, as was suggested in the earlier work. The potential increased with the speed only until the sparks began passing, when it fell sometimes as much as 4,000 volts. When the speed was further increased, the current increased but the potential remained practically constant. The following table shows the changes which occurred as the speed of the machine was increased:

Potential expressed in volts, current expressed in amperes. Distance between points, 18.05 cm.

TABLE 1.

Speed	Voltage before magnet was excited	Voltage with Magnetism	Current no Magnetism	Current with Magnetism	Type of discharge Effect of magnetism on form of discharge
1	23000	24000	.00014	.00014	Glow discharge.
2	24500	24500	.00017	.00017	" "
3	25300	25300	.00021	.00021	Small brush at anode.
4	26200	26200	.00025	.00025	Increased brush at anode.
5	26500	26500	.00029	.00029	Occasional spark.
6	27000	28300	.00035	.00035	Spark changed to brush by magnetism.
7	25300	28300	.00037	.00037	" " " " " "
8	24000	28300	.00044	.00044	" " " " " "
9	23000	28300	.00052	.00049	" " " " " "
10	22800	28300	.00059	.00054	" " " " " "
11	22800	28300	.00058	.00056	" " " " " "
12	23000	28300	.00065	.00059	" " " " " "
13	22800	28300	.00072	.00069	" partially changed to brush by magnetism.
14	22300	26500	.00078	.00076	" " " " " " "
15	22300	25000	.00083	.00083	Path curved but spark not stopped.
16	22300	25000	.00086	.00084	" " spark scattered.

In the above table, the current was measured by means of a Weston milli-ammeter, and the potential by means of an electroscope. This electroscope was made of two brass discs 10 cm. in diameter mounted in vertical planes on ebonite supports which were fitted to a common base. The distance between the plates could be varied by moving the supports. At the top of one of the discs was soldered a support holding a small needle upon which was suspended a brass vane which carried a pointer at the lower end. The pointer moved in front of a scale which was calibrated by connecting in multiple with the discs two No. 12 Thomas Harper needles (sharps), measuring the critical spark length between them and comparing with the table prepared by H. W. Fisher.[3] The position of the pointer was read through a telescope placed two meters in front of the scale. The potential read by this apparatus amounted to only a rough estimate, since it could not safely be trusted nearer than 150 volts. This was especially true when the sparks did not pass rapidly in succession because the vane

[3] H. W. Fisher, Transactions of International Electrical Congress, Vol. 2, pp. 294-312, St. Louis, 1904.

vibrated, rising almost to the critical spark potential, and falling almost to zero. In this case the mean position was recorded.

It may be observed from the above data that when the form of discharge was not changed by the magnetic field, there was no change in the current or the potential, and that when the form of discharge was changed there was an increase in the potential, and often a decrease in the current. The photographs of series A correspond to speed 1, B to speed 4, C to speed 6, and D to speed 16.

LONGITUDINAL MAGNETIC FIELD.

After taking the above data the magnet was turned through an angle of 90°, and four series of photographs taken of the discharge parallel with the lines of force. These are as follows:

E—silent glow discharge same as A.

F—brush discharge same as B.

G—spark discharge same as C.

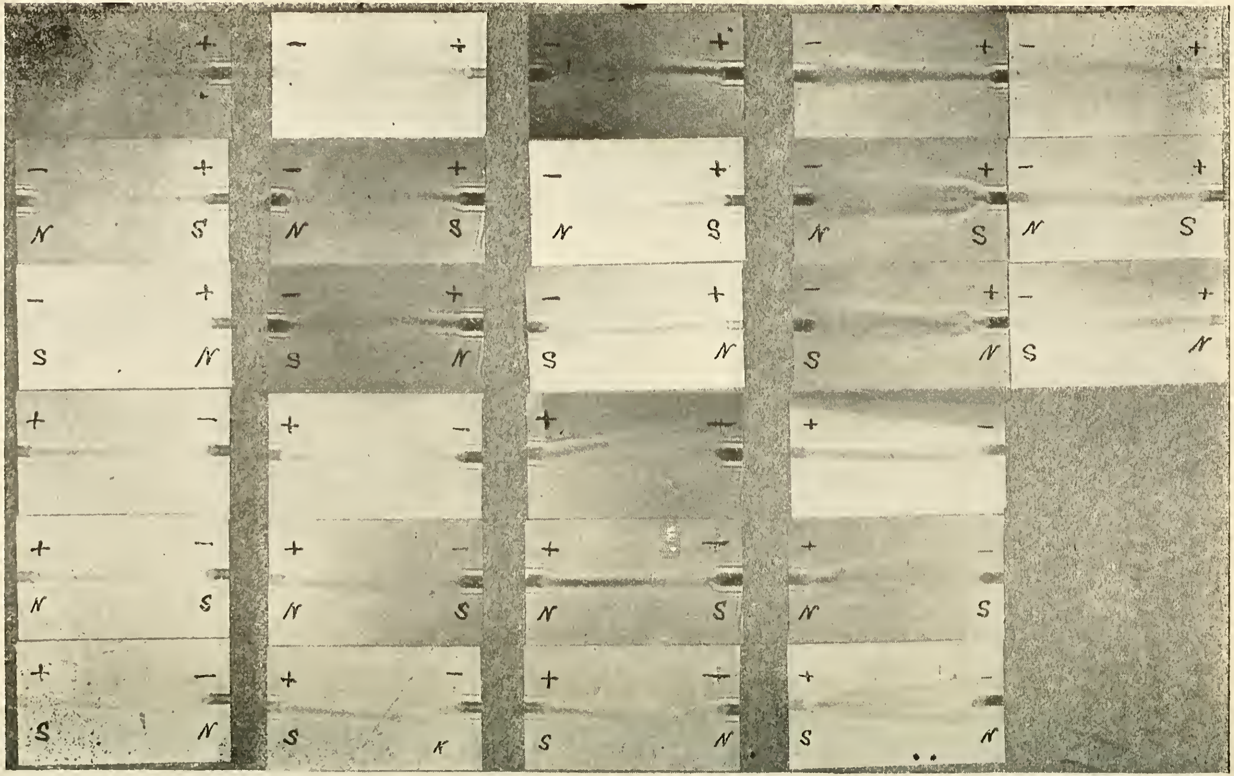
H—spark discharge same as D.

Distance between points, 17.88 mm.

Of these photographs, none show a change of form except those of series H. In this case the rich spark was sometimes scattered, and sometimes transformed to a wide violet brush at the positive point when the magnet was excited. In the first case it generally consisted of a visible undeflected central thread, with spiral thread encircling it like the threads of a tapering screw, the larger diameter of the spiral being at the positive point, and all merging together at the negative terminal. Sometimes, however, the central thread was absent and only the spiral showed. The sense of the rotation of the spiral was the same as that of the halo of luminous gases about the spark of an induction coil in a longitudinal magnetic field. In degree of deflection it was much less. In the case of the discharge studied here, the spiral was only a few millimeters in diameter in a magnetic field of 6,400 gausses, while the halo about the spark of an induction coil showed a spiral of four or five centimeters in diameter in a field of about 1,000 lines per square centimeter. Photographs 3 and 5 show the point discharge when the positive ions move in the same direction as the lines of force, while in Nos. 2 and 6 the magnetic field is in the opposite direction to that of the discharge. Unless there was a change of form of discharge, no change of potential nor of current occurred when the magnets were excited. Some changes of potential with transformation of form of discharge are as follows:

PLATE II. LONGITUDINAL MAGNETIC FIELD.

No. 1.
No. 2.
No. 3.
No. 4.
No. 5.
No. 6.



E. F. G. H^1. H^2.

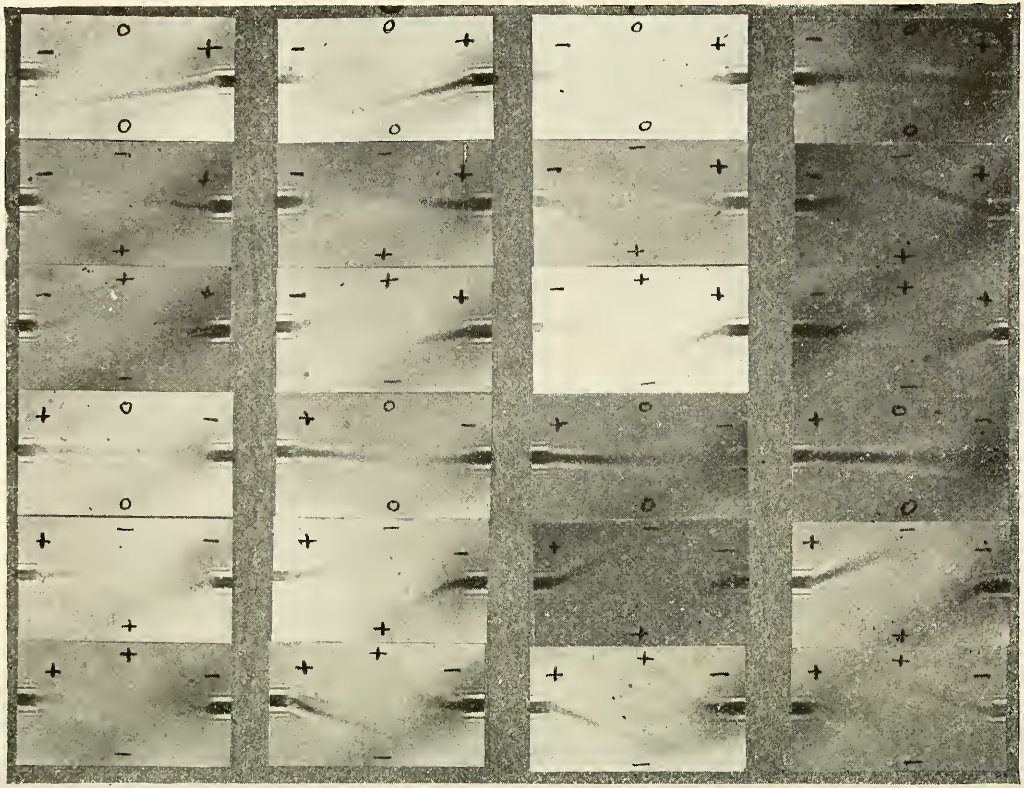
No. 1.	Current	1st,	No. 4.	Current	2nd direction,	magnetism (none).	
No. 2.	"	"	No. 5.	"	"	"	1st direction.
No. 3.	"	"	No. 6.	"	"	"	2nd "

TABLE 2.

Speed	Voltage before Magnet was excited	Voltage with Magnetism	Type of discharge Effect of Magnetism on form of discharge
1	21500	21500	Glow.
2	22000	21850	Small brush.
3	22500	22000	Occasional spark.
4	20000	22500	Changed to brush by magnetism.
5	22500	22500	No change.
6	20000	22500	Changed to brush.
7	18800	26500	" " "
8	18800	24000	" " "
9	18800	23500	" " "
10	18800	18800	No change.
11	18150	25000	Changed to brush.
11	18150	18150	Not changed to brush.
12	18150	18150	No change.
13	18150	24000	Changed to deflected scattered sparks.
14	18800	25000	Changed to brush.
15	18800	24000	Scattered deflected sparks.
16	18500	25000	Changed to brush.

The above table shows that there is no regularity in the changes in the discharge due to the influence of the magnetism. In No. 11 the spark discharge was entirely changed to brush for a while, then broke into a spark again, changing sometimes two or three times per minute. When the exciting current was stopped the sparking was again resumed. In the many complete sets of readings similar to the above it was found that this change appearing in No. 11 occurred for any of the spark discharges, but the actual condition that caused it was not discovered. One could not foretell when the discharge would be altered by the influence of the magnetism. Series H_2 shows photographs of the same sort of discharge as H_1, in which there was no change due to magnetism. These were taken twenty-four hours later than those of H_1, and on this particular day no change occurred in the discharge, when the current was in the direction shown in H_2, while on the previous day, with the same conditions in so far as apparatus was concerned, the spark was changed to brush every time the exciting current was closed, regardless of the direction of the magnetism. In series H_2 the spark was changed to brush by the magnetism when the other point was made positive, the photographs being like the corresponding ones of series H_1.

PLATE III. TRANSVERSE ELECTROSTATIC FIELD.



No. 1. No. 2. No. 3. No. 4. No 5. No. 6.

I. J. K. L.

No. 1. Current first direction, No. 4. Current second direction; no charge on plates.
No. 2. " " " No. 5. " " " upper plate negative.
No. 3. " " " No. 6. " " " " " positive.

TRANSVERSE ELECTROSTATIC FIELD.

The magnet was then removed and the deflection of the discharge studied in an electrostatic field. With the apparatus as previously described and with the electrostatic plates, the points and the electroscope shunted in parallel circuit, the four series of photographs I, J, K and L were taken. The following is a record of the potential and the current in each case, the forms of discharge for series I, J, K and L corresponding to those of A, B, C and D respectively:

Distance between points, 18.05 mm.

TABLE 3.

No. in Series		Charge on bottom Plate	Sign of Right hand point	Potential in Volts	Current in Amperes	
I	1	none	+	17850	.00019	
	2	+	+	17700	.00019	
	3	—	+	17600	.00016	
	4	none	—	16270	.00016	
	5	+	—	15150	.00015	
	6	—	—	16270	.00015	
J	1	none	+	18900	.00027	
	2	+	+	19425	.00036	
	3	—	+	19500	.00036	
	4	none	—	14700	.00026	
	5	+	—	17400	.00026	
	6	—	—	17250	.00026	
K	1	none	+	16800	.00039	
	2	+	+	17700	.00051	
	3	—	+	19200	.00052	Changed to brush.
	4	none	—	15600	.00052	
	5	+	—	17900	.00052	
	6	—	—	18370	.00051	Partially changed to brush.
L	1	none	+	16725	.00092	
	2	+	+	18000	.00089	
	3	—	+	17700	.00091	
	4	none	—	13950	.00088	
	5	+	—	16875	.00094	
	6	—	—	16800	.00090	

The variation of the potential and current in any series in the above table except for (3 and 6) K, was due to a decrease of speed of the motor. This was caused by a drop in potential when a large current was used in some other part of the building. It required at least two hours to complete the four series. The current and potential were read just before the photographic plate was exposed.

ELECTROSTATIC AND MAGNETIC FIELDS.

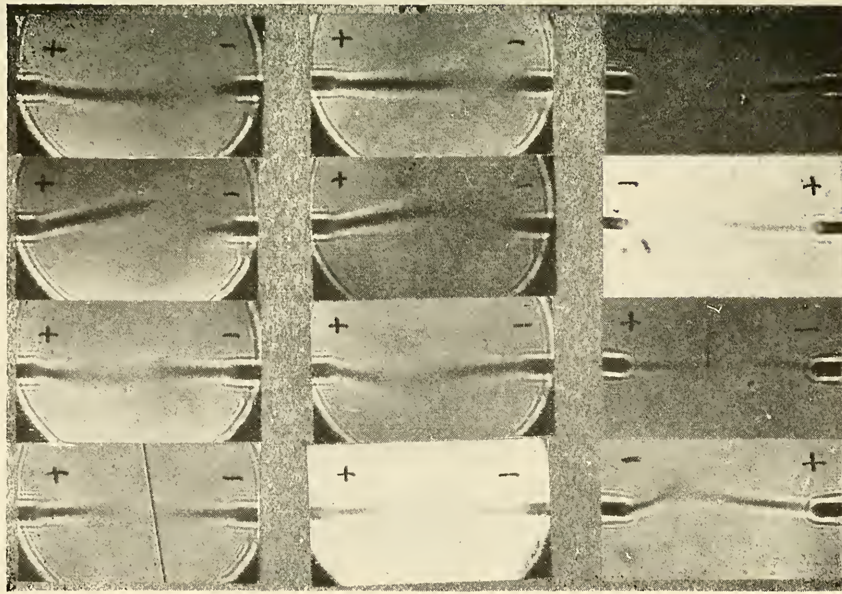
The magnet was again placed in the position so that the line of discharge between the points was transverse to the magnetic lines of force, and with the electrostatic plates above and below the points, an attempt was made to balance the effect of the electrostatic field against that of the magnetic field. In this work the plates were charged by a Holtz machine with plates 43 cm. in diameter. A ground glass placed in the end of the camera opposite the pinhole showed clearly the path of discharge. The speed of the Holtz machine and the strength of the exciting current of the magnet were then regulated until the stream under the action of both fields was the same as when no field influenced it; then, the ground glass was removed and was replaced by a photographic plate. Two series of these photographs are shown here, M, for the spark discharge which, under the influence of magnetism alone was changed to brush, and N for the rich spark. It was not difficult to balance the two fields in the case of the rich spark, but with the unstable spark they were not successfully balanced. Sometimes with this type a very low magnetic field seemed to predominate over the electric field. This, if true, conforms with the statement made in the previous report that the magnetic effect is greatest when the discharge is on the verge of changing from one form to the other. Data as follows:

Distance between points, 18.05 cm. H is the magnetic field strength in gausses.

TABLE 4.

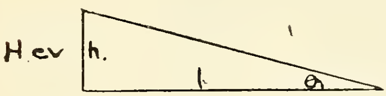
	Distance between Plates in cm.	Potential Difference in Volts	Potential Gradient = X	H	Velocity of Ion	Form of Discharge	Values for $\frac{e}{m}$	
1	5.4	14600	2710	4300	6.3×10^7	small brush	7.8×10^2	
2	5.4	14600	2710	4300	6.3×10^7	occasional spark	7.5×10^2	
3	5.4	15000	2780	2550	1.9×10^8	" "	7.1×10^3	
4	5.4	15000	2780	3800	7.4×10^7	rich spark	1.2×10^3	
5	6.1	26800	4360	1600	2.7×10^8	spark	1.36×10^3	Series M
6	6.1	26800	4360	1600	2.7×10^8	rich spark	1.36×10^3	Series N

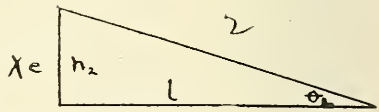
PLATE IV. ELECTROSTATIC AND MAGNETIC FIELDS.



No. 1. (M and N) magnetic and electrostatic fields opposed.
No. 2. (" " ") deflected by electrostatic field.
No, 3. (" " ") " " magnetic "
No. 4. (" " ") neither magnetic, nor electrostatic field.
Nos. (1 and 3) O discharge undisturbed.
Nos. (2 and 4) O " deflected by air stream.

It seems probable that the speed of the ion might be calculated from the relative deflection of a similar form of discharge under influence of the magnetic and electrostatic fields separately. The distance between the points was the same in both cases and therefore the potential at the points would, no doubt, remain of the same order, even though there was some change. On the photographs a line may be drawn directly between the points, and a second line drawn through the extremity of the negative electrode perpendicular to the first line. If then a third line is drawn from the positive point in the direction of the deflected stream and extended to meet the second line, the distance to the intercept of the second and third lines from the extremity of the negative electrode should be proportional to the deflection. Taking the distance to this intersection for the upward deflection, we have:





$Hev = K \tan \theta_1$, in case of the magnetic effect where H is the magnetic field strength in gausses, e the charge on the ion, v the speed of the ion, θ_1 the angle of deflection, and K is a constant which depends on the potential drop along the path of discharge.

In case of the electrostatic deflection, $X e = K \tan \theta_2$ where X is the potential gradient between the electrostatic plates and θ_2 the angle of deflection.

Solving each equation for K we have

$$K = \frac{Hev}{\tan\theta_1}, = \frac{Xe}{\tan\theta_2}$$

If the h_1 and h_2 are the distances from the negative point to the intercept in the two cases, and l the distance between the points, we have

$$(Hv \tan \theta_2 = X \tan \theta_1), \qquad \frac{Hvh_2}{l} = \frac{Xh_1}{l}, \text{ and } v = \frac{h_2 X}{h_2 H}$$

Since the discharge does not always pass directly between the points when no transverse field exists, it would probably be more accurate to take the average value of h for the upward and downward deflection. Making the suggested measurement in case of photographs 2 and 3 of series A and 2 and 3 of series I, we have

$$V = \frac{2.8 \times 17600 \times 10^8}{3.2 \times 5.1 \times 6400} = 4.7 \times 10^7 \text{ cm. per. sec.}$$

Values for other photographs calculated by the same method appear in Table 5.

The above values for the speed of the positive ions approximate those given for positive ions in rarefied gases. The highest value obtained by other investigators for the gaseous ion at atmospheric pressure, found recorded by the author, is by Helen E. Schaefer of 5×10^4 cm. per second. Her value, obtained by use of a rotating mirror, is given as the average speed along the spark path, and not the initial speed obtained by the method used in this investigation.

The curved path of the stream in series D can not be considered in connection with the ordinary formula for centripetal force in solving for a value for the ratio of the charge to the mass, because here the ion is under the influence of the charge on the opposite point. If, however, the value obtained by the above method can be regarded as the initial speed of the positive ion the equation $\frac{1}{2}mv^2 = Ve$ can be used to calculate the value for $\frac{e}{m}$. In the above equation m is the mass of the ion, v its speed, V the potential between the points and e the charge on the ion. Since v is the initial speed the two expressions for the energy are independent of the course taken by the ion between the points, and also independent of any subsequent speed. Some values of $\frac{e}{m}$ calculated by means of this expression are as follows:

Series A Nos. 2 and 3) $\frac{e}{m} = \frac{1}{2}\frac{v^2}{V} = \frac{1}{2}\frac{(4.7 \times 10^7)^2}{23000 \times 10^8} = 4.6 \times 10^2$ cm. per. sec.

TABLE 5.

Series.	Nos. in Series.	Speed v in cm. per. sec.	$\frac{e}{m}$
A and I	2 and 3	4.7×10^7	4.6×10^2
A " I	5 " 6	1×10^8	2.17×10^3
B " J	2 " 3	2.6×10^7	1.3×10^2
C " K	2 " 3	6×10^7	6.7×10^2
C " K	5 " 6	2.7×10^7	1.3×10^2
D		1.6×10^8	5.12×10^3

The average speed of all results is used in determining the value of $\frac{e}{m}$ given for series D. The values for $\frac{e}{m}$ column 4 are calculated for series A, B, C and D only. The values for $\frac{e}{m}$ given in table 4 are determined in the same manner as shown above.

A great variation exists in the calculated values of the speed, and consequently in the determination of $\frac{e}{m}$. One cause for this is, no doubt, the error introduced in measuring the potential. Also since the measurement of speed is determined by deflection, a large error may be introduced, due to convection currents, due to the heated air along the course of the spark, and to disturbances of the air due to rapid changes of pressure along the spark path.

It may be observed that the path of the stream from the point (except in case of the spark discharge in the magnetic field), is a straight line and not a curved path. There is very little if any bending to meet the opposite point. If we consider the stream as composed entirely of ions we might explain this phenomenon by supposing that the ions either lose their charge immediately after leaving the points, or by assuming that each ion is given a constant acceleration in two directions at right angles to each other. Another view may probably be taken in which the photographed stream is considered to be a mixture of ions and air molecules under different pressure than the surrounding air, hence having a different index of refraction. The ions start at a high speed from the point in a direction which depends on the influencing fields. They soon encounter molecules of air imparting their speed to a great extent to the air molecules. This bombardment on the air molecules tends to ionize them and to raise their temperature and the original ions, with the ionized and un-ionized molecules of air continue a short distance at least, in the original direction. The unionized air particles would continue along this line until scattered by encountering new molecules, while the ions, too much scattered, and with speed too much decreased to produce a well defined air current, travel by some other route to the opposite electrode.

This view explains the apparent contradiction that, although there must be a carrier of electricity between the points, the photographed stream does not terminate on the opposite point. In case of the rich spark, which takes on more and more the form of an arc as the speed of the machine increases, the air insulation is broken down, the air is more highly heated and more highly ionized along the spark path, and a greater number of ions will travel along this narrow path with great speed and due to the outer ones encountering the air molecules, the stream will follow more nearly the curvature of the spark. Farther from the point their speed becomes so small and they become so much scattered, they do not set up a stream so well defined. This same hypothesis applies to the explanation of the scattered stream when it was deflected by an electrostatic field. The stream retains practically its original diameter past the opposite terminal for the magnetic deflection in case of the glow and brush discharge, and although scattered may be traced nearly to the opposite point in the spark discharge. In case of the electrostatic deflection, the discharge without the transverse field is quite as well defined as those of the magnetic deflected series, while with the transverse electrostatic field the stream is short and not so well defined. If the ions moving with great speed start from the point, and soon by their bombardment start a current of air, at the same time lowering their own speed, they will certainly be scattered, part of them going to the oppositely charged plates, and part to the opposite point.

If the majority of the negative ions are considered to be ordinary electrons and those from the positive point equal in mass to the hydrogen atom, the kinetic energy of the positive ions will be far greater than the negative. They will therefore carry with them a greater current of air. Perhaps it may be permissible to assume that the negative ions are not all single electrons, since it has been shown by J. J. Thomson[4] in case of discharge is rarefied gases, that negative ions exist nearly equal in mass to the positive ions, and have the same initial speed. The greater the per cent. of these large ions the greater will be the amount of air set in motion, the greater the velocity of the stream as a whole, and the more defined the stream. If, then, the assumption is made that the stream is produced by the larger ions, it explains the equal deflection of the positive and negative streams in case of the magnetic deflection.

A few of the photographs show peculiar characteristics. In some there are two streams from the positive point. It was not learned whether

[4] J. J. Thomson (Phil. Mag. Ser. 6, Vol. 16, pp. 657-691), 1908; also (Phil. Mag. Ser. 6, Vol. 18, pp. 821-844), 1909.

this was caused by two branches of the discharge, or by a change of direction of the discharge during the exposure, but the clear interference bands about the stream indicate that the former is correct. Another is the peculiar deflection of the negative stream of No. 6 F. Many photographs were taken and many observations were made with the ground glass in an attempt to secure a duplicate of this, but with no success.

In the previous work the negative stream was not deflected by a magnetic field of 1,500 gausses, but in this the deflection was well shown where the stream is clear enough. The negative stream is in very few cases as long or as well defined as the positive. Also in the previous work, it was found that if the knobs of the electrostatic machine were placed sufficiently close together, a spark passed between them, while between the points there was a violet stream, which was not shown on the plate or perceptibly deflected by the magnetic field. An attempt to deflect this stream with a stronger field was not successful.

In repeating the work of Precht[1], particular attention was given to his observation with the point cathode and the blunt wire anode, that the spark changed to brush and the potential rose when the magnet was excited. The writer found that this change occurred in a great majority of the observations made, but it was found to occur also in as great a per cent. of the observations, whether the discharge passed between the points, point anode and blunt wire cathode, or point cathode and blunt wire anode, whatever the sense of the magnetism with reference to the current. In a few cases a brush would break into a rich spark, but all attempts to determine the conditions which caused the changes were unsuccessful. In the previous report it was suggested that in case of the discharge between two points the change in type of discharge might be explained as a result of a change of the spark length, but after repeating the experiment it was concluded, as was suggested by Precht[5], that although the length of spark path might be partly the cause, it was not the whole cause. No attempt was made to reproduce the exact condition of Precht's experiment either in the form or size of the point, but no doubt if these had been fulfilled the atmospheric and other conditions would have entered which would have made the results variable because with no part of the apparatus altered in any way entirely opposite transformations were found to exist on different days.

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[5] J. Precht, Wied. Annalen (66-4, pp. 676-697), 1898.

As a final study three mg. of radium bromide were placed beneath the points, in an attempt to change the form of discharge, as described by A. E. Garrett[6], for discharges between blunted wires. The radium, which was contained in an unstoppered glass tube, was held by an ebonite rod so that both α and β particles might reach the air in the path of discharge. No effect was observed except that which could be produced by a glass rod in the same position.

SUMMARY OF RESULTS.

A summary of the results, as given in this and the previous report, is:

(1) The positive stream between the points for a spark or brush discharge was deflected by a magnetic field as low as 1,000 gausses, and both positive and negative streams for glow, spark and brush discharge were deflected by a magnetic field of 6,400 gausses. In all cases the direction of deflection was in accordance with electro-dynamical laws.

(2) In most cases a change of type of discharge, and an increase of potential between the points was caused by excitation of the magnet.

(3) The direction of the photographed stream for a spark discharge as it leaves the point is the same as the visible direction of the spark.

(4) The size of the stream at the points (measured with a micrometer microscope between the outer edges of the central dark band) is independent of the potential between the points.

(5) The stream was deflected by an air current, the negative being deflected more than the positive.

(6) The stream for the richer spark (i. e., for the higher speeds of the machine) increased in width as the distance from the point increased, while the stream for the glow discharge retained its original size as far as it could be traced.

(7) The stream was deflected by an electrostatic field, in which case it was shorter and more scattered than in case of the magnetic deflection.

(8) Values for the speed of the ion were calculated from the angle of deflection, in magnetic and electrostatic fields, and by placing the two fields in opposition. The average of these was 1.6×10^{8} cm. per second.

(9) From the kinetic energy of the moving ion and the product of the potential between the points and the charge on the ion values for $\frac{e}{m}$ are calculated, the average value found being 1.8×10^{3}.

[6]A. E. Garrett, B. Sc.—The Phys. Soc. of London Proceedings, Dec. 1909, page 643.

(10) A suggestion is given that the stream consists of heated air molecules and ions, in which the latter soon lose their velocity, due to encountering air molecules, and travel to the opposite point with a speed too much decreased to set up an air current, along a route determined by the two fields, while the un-ionized air moves in the direction given it by the ions at the point.

The above investigation was suggested by Professor Arthur L. Foley, of Indiana University. I wish to thank him and Professor R. R. Ramsey for their helpful suggestions during the course of the investigation. I wish also to thank Professore A. T. Jones and C. M. Smith, of Purdue University, for their criticism during the preparation of this report.

Physical Laboratory of Indiana University,
Bloomington, Ind.