THE SILENT ELECTRIC DISCHARGE AND ITS EFFECTS ON GASES.

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In order to determine the causes for the erratic behavior of gases when subjected to a silent electric discharge the Engineering Experiment Station at Purdue University has been conducting an investigation of alternating current discharge in an attempt to obtain further knowledge of its mechanism. This investigation has continued over a period of about four years in conjunction with the problem of the fixation of atmospheric nitrogen by the silent electric discharge.[1]

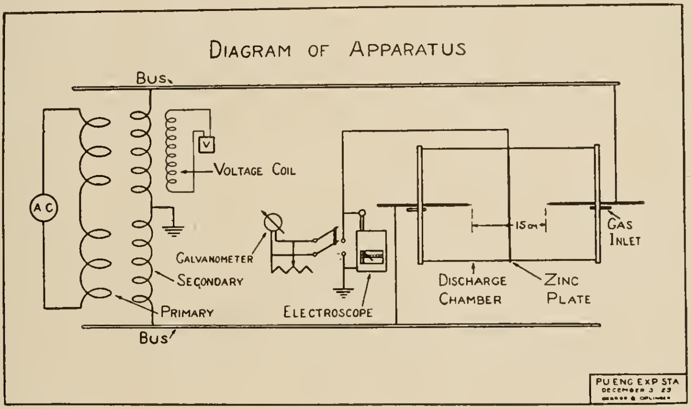

Fig. 1. Diagram of a corona discharge apparatus and power supply circuits.

In the beginning only the discharge in air was considered but the problem here was so complex that an attempt was made to simplify it by studying the discharge in the component gases. The work set forth in this paper is a résumé of recent investigations in the two gases, nitrogen and oxygen.

The discharge chamber as shown in figure 1 is made up of glass plates cemented together at the edges and to the bakelite end pieces. The gas was admitted at each end and allowed to pass out through a small opening in the top near the center of the chamber. The needles used were made by drawing down a 2 mm. glass tube and sealing into it a short piece of tungsten wire 0.27 mm. in diameter which extended out beyond the glass a distance of 3 mm. and was carefully ground to a point. The needles were then centered in the chamber with a distance of 15 cm. between points. Connections were made to the tungsten points by filling the glass tubes with mercury.

[1] See Bulletin No. 9, Engineering Experiment Station, Lafayette, Indiana, for a detailed description of this work.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

In nitrogen a very beautiful discharge is obtained which extends from one needle to the other and is made up of many fine streamers of glow discharge.

The discharge in oxygen is scarcely visible up to the sparking potential, which is almost double that of nitrogen. We were unable to obtain a photographic record of this discharge as even the slight glow of the points failed to show up on the photographic plates.

The discharge in nitrogen with an insulated zinc plate placed midway between the two needles is represented in figure 2. This picture has been retouched and the uneven joint in the center of the discharge chamber is cut out. The presence of the plate increased the sparking potential about 50 per cent. If the discharge at the point is closely studied it is seen that from the neck of the discharge many small

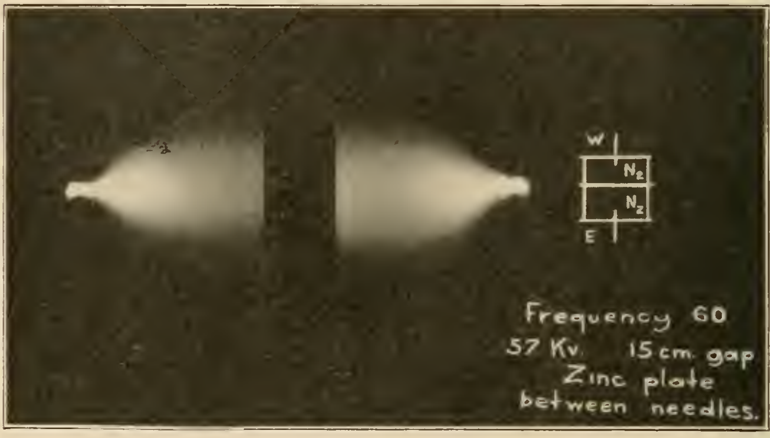

Fig. 2. Discharge in nitrogen with zinc plate between needle electrodes.

branches form at definite intervals. This formation seems to indicate that the discharge is composed of a number of concentric cones.

This structure of the discharge was still further substantiated by a study of the zinc plate after it had been in the discharge for a short time. Sections of the plate were roughened giving the concentric circles shown in figure 3. The light portion represents the roughened surface and the darker portion indicates where the plate retained much of its original polish. Due to the fact that most of the static sparks struck within the inner circle this section is roughened more than any other.

Although the discharge, as represented in figure 2, appears continuous to the eye it is actually made up of two distinct types of discharge, the images of which are superimposed. By means of a special camera[2] these two can be separated and drawn out along a time axis. Figure 4 represents the discharge in nitrogen at 60 cycles

[2] McEachron, Karl B., "Two Photographic Methods of Studying High-Voltage Discharges", Amer. Inst. Elec. Eng., Vol. 42, No. 10, 1923, pp. 1045-1050.

taken with this camera. The scale at the top and bottom gives the number of electrical degrees passed through with respect to time in the direction shown. The negative discharge appears as a line which represents a concentrated glow on the needle point, while the positive discharge gives the characteristic brush extending from the needle

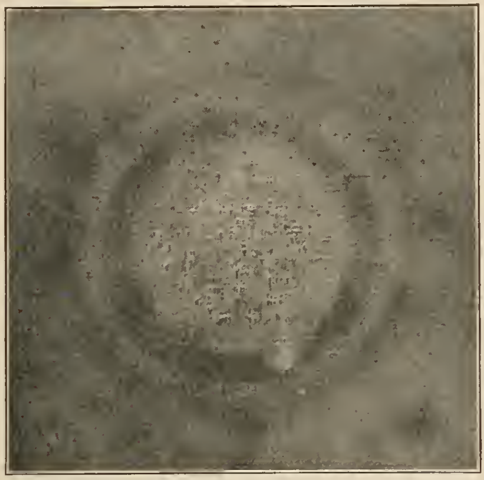

Fig. 3. Photograph of zinc plate showing effects of discharge on the metal.

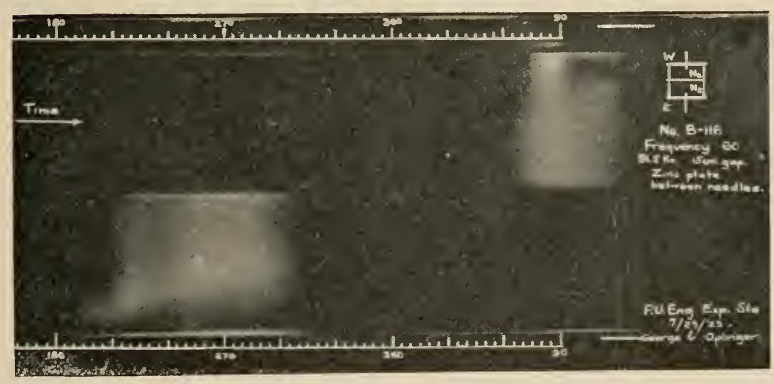

Fig. 4. Corona discharge in nitrogen taken with revolving mirror camera.

point to the zinc plate. In the positive brush, a short distance from the needle may be seen a dark space. This represents a space between the end of the neck and the brush where there is either no radiation or where the radiation is of such wave length that it does not affect the photographic film. Pictures taken without the zinc plate show the luminous discharge extending from one needle to the other.

Experiments conducted by Francis E. Nipher[3] show that this luminous column terminates on the plate and becomes longer or shorter depending upon the distance of the plate from the positive needle.

A 5 mm. hole was made in the center of the zinc plate to see if the corona would pass through this hole to the other needle. It was found that if enough sparks had taken place to ionize the gas sufficiently, the discharge would pass through the hole. By blowing nitrogen in one end of the apparatus, through the hole, and out the other end it was possible to obtain a unidirectional discharge as shown in figure 5. Here the luminous discharge follows the flow of gas through the hole. The positive brush from the W needle is unable to form against the stream of ionized gas flowing through the hole.

During previous work with alternating current discharges it was noted that an insulated plate placed between needle points appeared

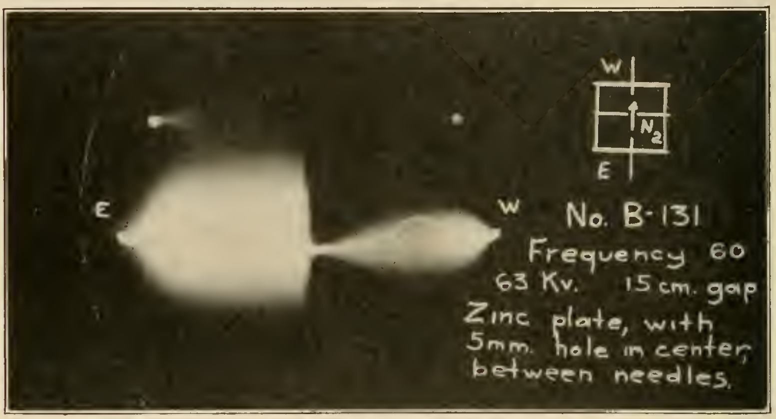

Fig. 5. Discharge in nitrogen passing through hole in zinc plate. Note unidirectional effect.

to pick up a positive charge as small brushes of positive corona would form on the edges of the plate when a spark occurred between the needles and the plate. In order to determine the nature and amount of this charge the zinc plate was connected so that it might either be grounded through a galvanometer or connected to an electroscope as shown in figure 1. With this arrangement the charge on the plate is determined by the electroscope and any difference in the postive and negative discharge current when the plate is grounded is measured by the galvanometer. Some difficulty was experienced in getting an electroscope of sufficient range to read all voltages on the plate with any degree of accuracy.

Two sets of tests were made with each gas, one to determine the effect of voltage on the plate current and potential when the gas is fresh and the other to determine the time effect of discharge with an

[3] Experimental Studies in Electricity and Magnetism, Blakiston's Sons Co., Philadelphia, 1914, p. 3.

enclosed volume of gas. Before taking data with different gases, the gas was blown through the apparatus for approximately one hour at the rate of about 5 liters per minute. In the case of tests with the same gas, 30 to 45 minutes was considered long enough to remove all traces of contaminated gas.

Figure 6 gives the results of these tests in oxygen. With gas blowing through the apparatus, when determining the effect of voltage, the readings were taken as rapidly as possible, the plate being grounded only long enough to take a reading on the galvanometer. From the curve it is seen that the current continues to increase in a negative direction with an increase in voltage until the sparking potential is

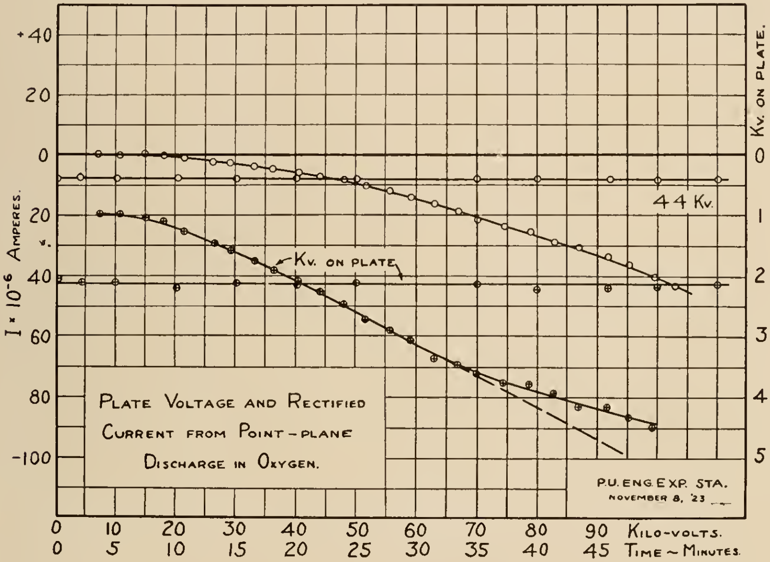

Fig. 6. Rectified current in oxygen.

reached. The effect of time upon the current is very slight, as shown by the other curve taken at a constant voltage of 44 kv. A charge as high as 4 kv. was found to exist on the plate.

The results with nitrogen were quite different and are given in figure 7. Two sets of tests as shown by the solid and dotted curves, were made upon the same day, and check fairly close. With an increase in voltage the negative current increases until at 37 kv. a very definite change in characteristics of the gas takes place. This is shown by the scattering of the points at this portion of the curve and by the sudden decided decrease of the negative current. As the voltage is still further increased the current falls to zero and becomes positive at the sparking potential.

In these experiments the voltage readings were unsatisfactory due to the large variation in plate voltage. A high voltage electroscope was used which was not sensitive at the low values. The maximum negative potential which the plate attained was 7 kv. with an impressed voltage of 30 kv. between needles, which means that the voltage

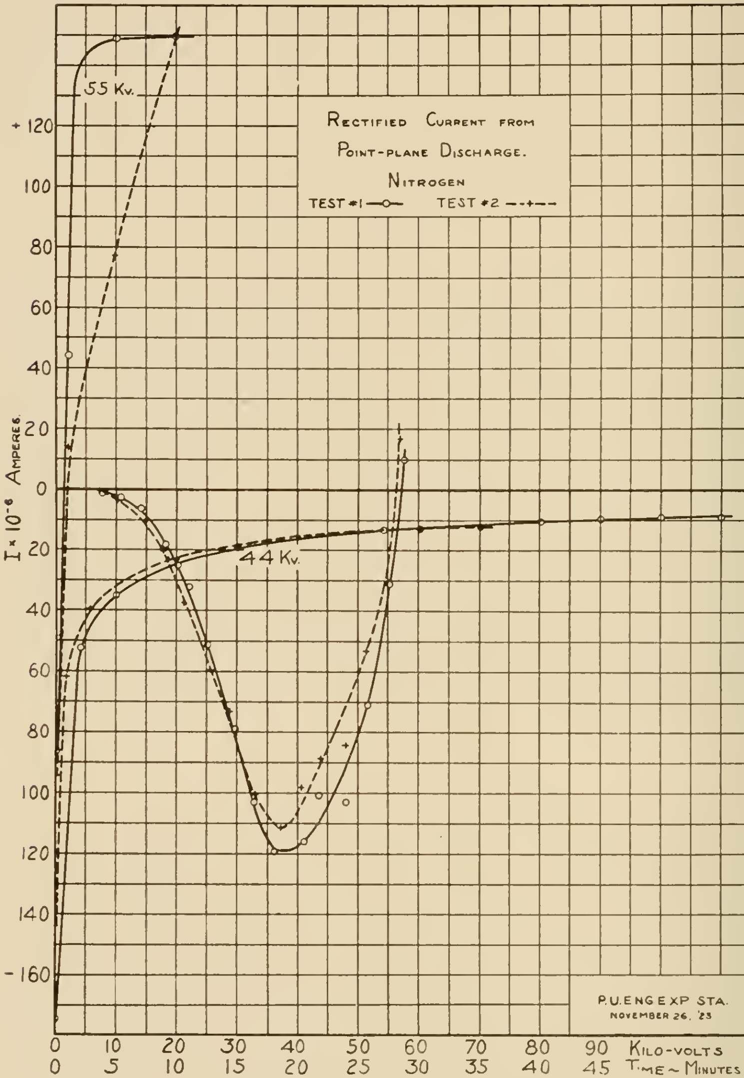

Fig. 7. Rectified current in nitrogen.

from the negative point to the plate was 8 kv., and from the postive point to the plate was 22 kv. with the same current flowing at each needle.

TABLE I.—VOLTAGE DISTRIBUTION BETWEEN ELECTRODES AND PLATE

Potentials in Kilovolts				Plate to Ground Current $I \cdot 10^6$
Between Needles	Plate to Ground	Needle to Plate		
		Positive	Negative	
7.1	−0.76	4.31	2.79	− 0.29
14.1	−1.77	8.82	5.28	− 5.5
21.1	−2.67	13.22	7.88	−20.8
25.5	−3.0	15.75	9.75	−30.9
32.7	−3.32	19.67	13.03	−54.9
40.8	−2.02	22.43	18.38	−68.0
47.5	−0.95	24.7	22.8	−25.5
51.5	+0.87	24.62	26.88	+19.6
54.0	+2.02	24.98	29.02	+173.2

Table I shows the voltage characteristic for nitrogen which was slightly contaminated. The low plate voltages which fell within the range of one electroscope were due to contamination.

It is unfortunate that we were unable to measure the total current supplied to the needles and thus determine whether there was a large increase in current when the voltage between the positive needle and plate reached 24 kv.

The large negative current at 44 kv. decreased very rapidly with time as brought out by the curve of figure 7, but does not reverse. However, at 55 kv. the current reversed very soon after the voltage was applied and attained a very high positive value.

The following factors may assist in the production of the phenomena observed in the case of nitrogen:

1. Electron emission from the zinc plate by postive ion bombardment.
2. Ionization by collision with positive ions.
3. The formation of large negative ions due to activation of the gas.
4. Photoelectric effect produced by the action of the ultraviolet light on the zinc plate.

From the voltage data it would appear that numbers 1 and 2 were the controlling factors, but they do not explain the initial voltage and current characteristics found when the gas has previously been subjected to the discharge. Evidently the gas undergoes a change, probably in the positive discharge, from which, it does not recover for several hours. The question of whether the molecules acquire the ability to pick up electrons from the negative discharge and thus decrease their mobility must be left for future investigation with high-voltage direct current.

SUMMARY AND CONCLUSIONS.

1. The sparking potential between points in fresh nitrogen is roughly 60 per cent of that value for oxygen under the same conditions.

2. If nitrogen has been subjected to heavy sparking its sparking potential is reduced and remains so for some time.

3. The presence of a metal plate midway between the electrodes increases the sparking potential in nitrogen from 30 to 60 per cent but has no appreciable effect in the case of oxygen.

4. The sparking potential with a 5 mm. hole in the metal plate is only slightly greater than that of the gap alone.

5. If a metal plate is placed midway between points discharging in nitrogen, it acquires, at low potentials, a strong negative charge, but if the voltage is increased sufficiently, the sign of the charge is reversed. If the discharge takes place in oxygen the negative charge acquired by the plate is very much less than for nitrogen, but continues to increase up to the sparking potential.

6. The effect of time of discharge at constant potential, on an enclosed volume of nitrogen, is to cause a reduction in the initial negative charge on the plate, which under certain conditions may change sign and become positive.

7. Oxygen is consistent in its behavior under the influence of the discharge.

8. The discharge in nitrogen takes a number of forms depending upon potential, previous history of the gas, time of discharge and material placed in the path of the discharge. This indicates the formation of an activated nitrogen whose electrical properties are greatly different from those of the unaffected gas.

9. Measurement of the charge acquired by a metal plate placed between needles discharging in nitrogen might possibly be used to determine when nitrogen is in the proper state to unite with other elements.

A more complete account of this work together with much other material will be found in an Engineering Experiment Station Bulletin to be published in the near future.

The gas used in these experiments was kindly donated by the Cleveland Wire Division of the National Lamp Works through the courtesy of Mr. B. L. Benbow.