Some Strange Oscillatory Discharge-Figures on Photographic Plates

By

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Abstract

Certain strange discharge-figures are impressed on photographic plates when oscillatory discharges, first negative and then positive, take place at an electrode placed on the plates. The figures thus taken at low air pressures have a strikingly different structure from the ordinary ones obtained with a single discharge, but they are very like those showing the "reversal-like phenomena" which are produced by fogging the photographic plates with a spark simultaneously with the impression of the discharge-figures.

An explanation of these strange oscillatory discharge-figures is given on the same lines as that of the "reversal-like phenomenon."

In an earlier investigation[1] on the discharge-figure impressed on photographic plates, the writer found an interesting positive figure due to the oscillatory discharge of a condenser charged positively, and pointed out a distinct difference between this and the ordinary positive figure. In these interesting positive figures (see Fig. 4 and Fig. 5 in Plate II of that paper), it has been noticed that the figures generally consist of two parts: (1) an indefinite circular part at the centre, from which some short brushes radiate outwards, and (2) some intense branches starting from the centre of the former, from whose ends irregular branches grow outwards and fit themselves in proper order into the space between the brushes of (1). From these features, it seemed to the writer that part (1) was formed by the first discharge at the electrode and part (2) by the next discharge.

In the present paper, we shall investigate the negative figures

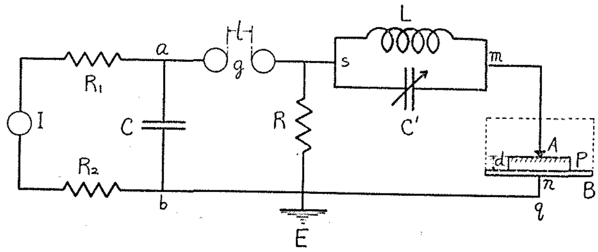
1. T. Terada: These Memoirs, 13, 281 (1930)

which are obtained with similar experimental arrangements, but which are due to the oscillatory discharge of a condenser negatively charged.

(I) The Figures obtained with an Oscillatory Circuit consisting of an Inductance and a Capacity

The letters used in Fig. 1 have the same significance as in Fig. 3 of the earlier paper; namely, I is an induction coil or an influence

Fig. 1.



machine, R_1 and R_2 great resistances, R another resistance, L an inductance, C a condenser of about 4,000 cms., C′ a variable air condenser, and P is a photographic plate placed on an earthed metal plate B. The photographic plate P is enclosed, with an electrode A laid on it, in a sealed bell-jar provided with an exhaust arrangement.

In order to get undamped electrical oscillation in the branched circuit (L–C′), it is necessary to use a greater shunt resistance R and a smaller electrode A, because the logarithmic decrement of the circuit depends upon the energy-loss transferred during the periodic time, and among the causes of the losses of electric energy, those due to the shunt resistance and the formation of the figure are especially predominant in our case. Fig. 1 in Plate I is a negative figure obtained with the spark gap $l=1$ mm. and the shunt resistance R = 1 megohm, and at a low air pressure of about 120 mm. Hg. The wave-length λ of the oscillation in our branched circuit could be measured by means of a wave-meter by passing sparks successively at the gap g, though the oscillation was not strong. In our case it was about 100 meters. Generally speaking, this figure consists of two parts: namely, (1) a central diffuse portion from whose center well-known irregular positive branches start outwards, (2) a continuous margin just at the end of the former, leaving a narrow dark unaffected portion between this margin and part (1).

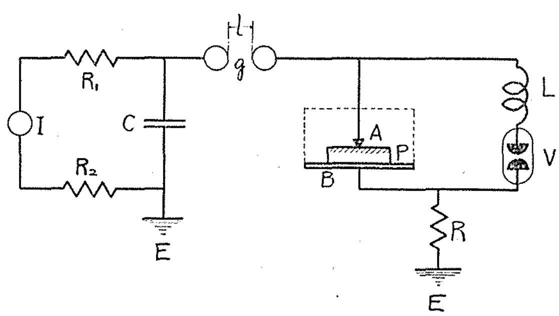
Next, in order to get the negative discharge-figure which will be impressed on a photographic plate when many oscillatory discharges occur at the electrode, the thickness d of the insulating plate was increased to 2 mm. or more to reduce the energy-loss on the formation of a figure. Fig. 2 in Plate I was obtained with $d=2$ mm., $l=1.2$ mm., air pressure $p=150$ mm. Hg, R=1 megohm and $\lambda=25{,}000$ m. In this, we can see two negative enveloping rings similar to that in Fig. 1 in the same plate and also many positive branches radiating from the electrode. Some of the positive branches appearing near the electrode seemed to differ a little from the ordinary ones: their side portions were a little stronger in intensity than the inside, though this might not be clearly reproduced.

In order to make clearer the features of such positive branches, many photographs were next taken with other oscillatory circuits in which the oscillations were a little longer and stronger than in the former cases.

(II) The Figure obtained by an Oscillatory Circuit with a Low-pressure Discharge-tube

As many observers[1] have noticed, it is possible to generate electric oscillations with an audio or radio frequency by the aid of a discharge-tube containing gas at low pressure. In Fig. 2, I, R_1, R_2, C, g, A, P, B and L have the same significance as in Fig. 1. V is a discharge-

Fig. 2.



1. R. Bär: Handbuch der Physik, (Geiger und Scheel) XIV, 178 (1927)
K. G. Emeléus: The conduction of electricity through gases, 19 (1929)
E. W. B. Gill: Phil. Mag. **8**, 955 (1929)

tube with aluminium electrodes whose air pressures were generally below a few millimetres of mercury but varied within wide limits. If, as the right hand-side in the figure makes an oscillatory circuit, direct current-discharges pass through the gas in tube V, oscillations will occur in the circuit ALVBA and consequently the discharges-negative and then positive- will take place at the electrode A several times. The wave thus obtained may also be of sinusoidal form as is often the case with oscillations produced by a discharge-tube. However, the wave-length of the oscillation in this case could be easily measured by means of the precision wave-meter, for the oscillation was stronger than in the former cases.

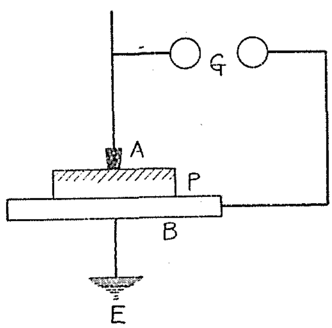
Fig. 3 in Plate I was obtained with such an experimental arrangement; that is to say, the condenser C was negatively charged and $l=1.3$ mm., $d=2.5$ mm., R=3,400 ohms, $p=65$ mm. Hg, and $\lambda=1{,}800$ m. From this, as we expected, it seems that the oscillations lasted for a comparatively long time and consequently three or more negative and two or more positive discharges occurred at the electrode one after another. In this figure, there are two or more concentric rings which are essentially the same as the enveloping margin in Fig. 1 or those in Fig. 2 in the same plate, though they are rather too faint to give a clear reproduction. And also, we can distinctly see two kinds of positive branches in this; namely (1) the ordinary positive branches which were perhaps due to the first positive discharge, (2) peculiar positive branches as if a photographic reversal had taken place, which were probably impressed on the photographic plate by the second positive discharge (i. e. this was preceded by the first negative and positive and the second negative discharges).

To establish the relations between the occurrence of these strange phenomena and the periodic time of the discharges at the electrode, many photographs were made with oscillatory circuits with various periodic times. By changing the air pressure in the discharge-tube or the inductance L, the wave-lengths were varied between very wide limits from 60 to 25,000 meters or more, and the experimental results suggested that the occurrence of the phenomena would be nearly independent of the periodic time of oscillations produced in the circuits so long as the oscillatory discharges occurred at the electrode.

(III) An Explanation of the Strange Oscillatory Discharge-Figures

In Fig. 3, A, P and B have exactly the same meaning as in the previous figures. G is a spark gap inserted between the electrode A and the earthed metal plate B. If a discharge-figure—positive or negative—is impressed on the photographic plate P, and at the same time a fogging spark passes over the gap G, an interesting phenomenon occurs in the figure as Prof. U. Yoshida[1] first pointed out. In the negative, a diffuse enveloping margin appears just at the ends of the regular negative branches, leaving a nearly unaffected narrow area between them (see Fig. 4 in Plate I). In the positive, each branch is enveloped by a rather diffuse margin (see Fig. 5 in the same plate). The writer will call this the "reversal-like phenomenon" as in his earlier paper[2].

Fig. 3



In that paper, the writer tried to give an explanation of the occurrence of the phenomenon from the facts: (1) the wave-length of the fogging light which was effective in the phenomenon was shorter than about 420 $\mu\mu$ as pointed out by Prof. U. Yoshida and J. Tsutsumi[3], (2) the features of the figures showing these phenomena were very like those of dust-figures, and (3) similar phenomena occurred in the discharge-figures impressed on photographic plates which had been previously charged with electricity in some way though they were too faint to be reproduced in that paper.

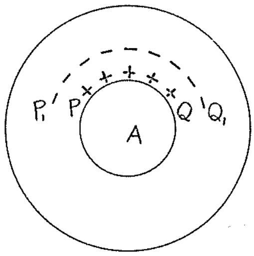
Now, comparing the features of the enveloping margins of the strange oscillatory figures with those showing the "reversal-like phenomena"—compare Fig. 1 with Fig. 4 in Plate I and also Fig. 3 with Fig. 5 in the same plate—, it seems probable that these phenomena are due to the same causes.

Let us assume that, in Fig. 4, the greater circle denotes the range of the first negative figure. Just after the impression of this,

1. U. Yoshida: These Memoirs **2**, 315 (1917)
2. T. Terada: These Memoirs **12**, 217 (1929)
3. U. Yoshida and J. Tsutsumi: These Memoirs **11**, 267 (1928)

numerous negative ions and some positive ions will be left within the range and their number may be increased by the following positive discharge at the electrode A. If at this stage, the second negative discharge-figure is impressed on the plate and its range is denoted by the smaller circle in Fig. 4, the positive ions thus produced on the plate will be attracted inwards and left in a layer PQ just at the edge of the second negative, but numerous negative ions or electrons will be repelled outwards and crowd in the other layer P_1Q_1 in the manner shown in Fig. 4. As this will bring forth a weak electric field in the portion between the layers PQ and P_1Q_1 and a strong field in the layer P_1Q_1 or a little outside it, the negative enveloping margin will be formed in that portion where the strong field is, as a result of ionization caused by collision of the ions with air molecules, and will miss the unaffected dark ring at the weak portion of the field between the layers PQ and P_1Q_1 as stated in the writer's earlier paper in the explanation of the "reversal-like phenomenon." Thus, the negative enveloping margin of Fig. 1 in Plate I may be produced. From this point of view, it follows that if several negative discharges caused by an oscillatory circuit take place at an electrode placed on a photographic plate, the phenomena mentioned above should occur for successive pairs of them. The diffuse concentric rings in Fig. 2 in Plate I were probably produced in this manner.

Fig. 4



If there is no great mistake in this explanation, we should also be able to get similar figures by other methods which can cause successive negative discharges at an electrode placed on a photographic plate. This was found to be true: similar figures have been obtained on dried photographic plates at low air pressures when two or more negative discharge-figures were successively impressed, within a few seconds, the ordinary arrangement being used, but they were a little too faint to be reproduced.

It seems to the writer that the enveloping margin of the positive branches in the oscillatory figure (Fig. 3 in Plate I) is essentially the same as the negative margin in Fig. 1 in the same plate and consequently the explanation given above is also applicable to the positive. The main difference between them seems to be only the arrangement of the branches, but it is hardly necessary to mention the point, for it was fully described in the earlier paper[1]. The only question left to be explained is why the positive branches, which were impressed after the first negative, are not enveloped by the margin (i. e. we can not see the enveloping margin in the positive branches in Fig. 1, Plate I). This may be simply that the number of ions, especially the positive ions, was insufficient to make the portions of the weak and the strong electric field distinct and consequently, the enveloping margin was not produced in the positive branches in Fig. 1, Plate I.

In a word, the main result of the investigations mentioned hitherto is that the strange oscillatory figures are none other than those giving rise to the "reversal-like phenomena" and that both the previous discharges of the oscillatory figure and the 'fogging spark in the "reversal-like phenomenon" have the same influence upon the positive and negative figures in question.

In conclusion the writer's sincere thanks are due to Prof. U. Yoshida of the Kyoto Imperial University for the interest he has taken on the research.

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1. T. Terada: loc. cit. (1929)

Plate I

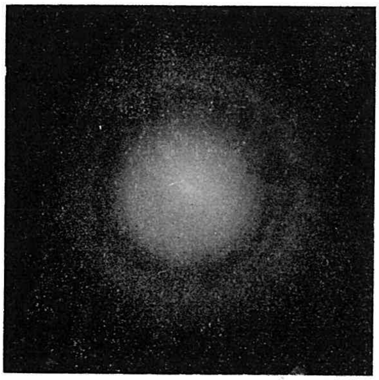

Fig. 1
l = 1mm. d = 1.2mm. R = 1 meg.
λ = 100m. p = 120mm. *Hg.*

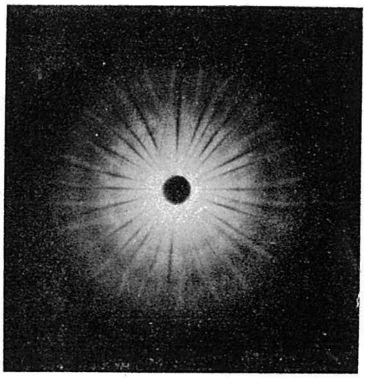

Fig. 2
l = 1.2mm. d = 2mm. R = 1 meg.
λ = 25,000m. p = 150mm. *Hg.*

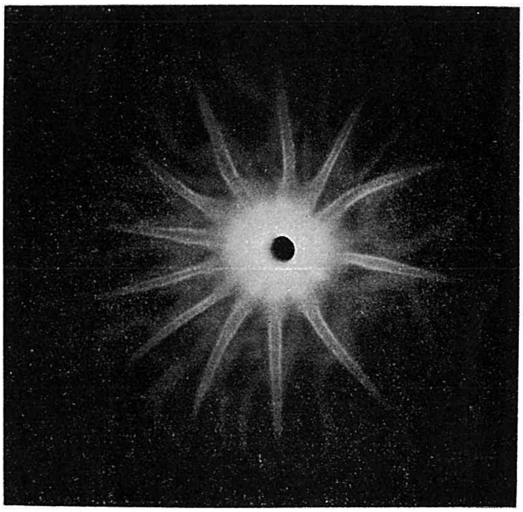

Fig. 3
l = 1.3mm. d = 2.5mm. R = 3,400 ohms.
λ = 1,800m. p = 65 mm. *Hg.*

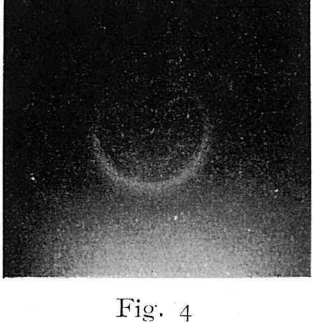

Fig. 4
l = 2.5mm. p = 760mm. *Hg.*

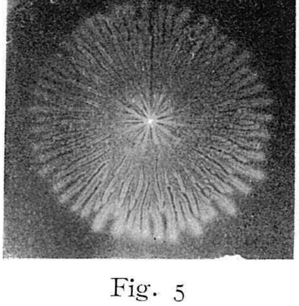

Fig. 5
l = 2.5mm. p = 760mm. *Hg.*