OSCILLOGRAPHIC STUDIES OF STRIATED ELECTRIC DISCHARGE

By

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With 5 Plates

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INTRODUCTION

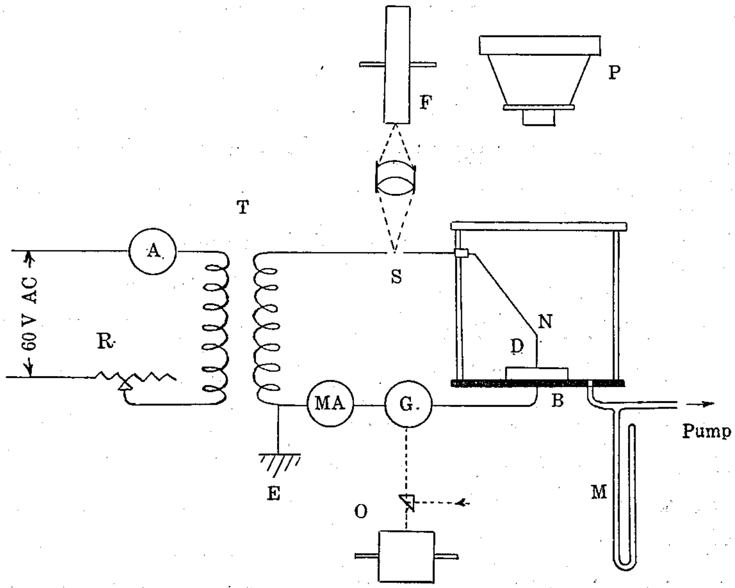
In the course of obtaining the characteristic striated figure of electric discharge, a high alternating electromotive force from the secondary of a transformer was applied as source. We observed by means of a D.C. galvanometer connected series to the discharge circuit that the electric current was considerably rectified when that circuit was so regulated as to cause the striated figure itself[(1)] to appear. Since making an earlier report, we have had the opportunity to use an oscillograph and also a camera with rotating photographic film, the latter of which was devised by a few members of this Institute.[(2)] Thus we could study the properties of the striated discharge especially from the viewpoint of the distribution of the discharge current.

I. APPARATUS FOR THE EXPERIMENT

The oscillograph used in our measurement was made by Yokogawa Factory in Japan. The frequency of oscillation of the galvanometer is 12000 per second. We connected the galvanometer directly in series to the discharging system. The apparatus and the electric connections are shown roughly in Fig. 1.

(1) T. ITOH: Proc. Imp. Acad., **5** (1929), 5–8.
(2) Y. IKEDA, E. KATO and M. MORI: Proc. Imp. Acad., **5** (1929), 227–229.

The transformer and the discharge vessel used are the same ones as reported previously.[3] The ratio of turns of the transformer is 60 to 100000. The series gap consists of two conical ends of steel. The needle in the discharge vessel is of steel of about 5 cm. length and 0.05 cm. diameter at the middle, and is lead by some thick brass wire (0.3 cm. diameter) out of the vessel. A circular glass plate is put between the needle point and the brass base (the latter two composing themselves as electrodes).



R: Sliding resistance
P: Photographic camera
A: A. C. ammeter
T: Transformer
S: Spark gap
MA: D. C. Milliammeter
G: Vibration galva. attached to O.
O: Oscillograph
F: Camera and rotating film
N: Needle
D: Dielectric plate
B: Brass plate
M: Mercury manometer

Fig. 1.

(3) T. ITOH: The Memoirs of the Faculty of Engineering, Hokkaido Imperial University, **1**, (1928), 241.

The camera with rotating photographic film is set, quite independent of the electric circuit, to take photographs of the sparks occurring across the series gap S.

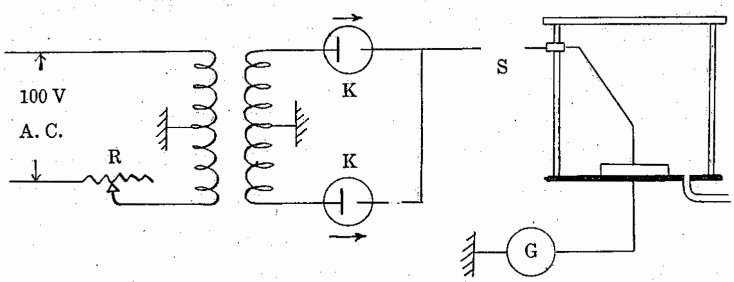
In the present measurement the gas in the discharge vessel was air the pressure of which was reduced by a Cenco pump. As the dielectric in the discharge vessel we used two kinds of circular plates of ordinary window glass. One of them has 15 cm. diameter and 0.18 cm. thickness, and the other 10 cm. diameter and 1.5 cm. thickness consisting of nine sheets of glass: we call them No. I and No. II for simplicity.

II. OSCILLOGRAPHIC INVESTIGATIONS OF THE STRIATED DISCHARGE

Figs. 2, 3 are reproductions of photographs taken with No. I as dielectric and keeping the primary electric current to 2.5 A. The discharge corresponding to Fig. 3 took place with smaller series spark gap than that to Fig. 2. We see the number of striae of one of these discharge figure to be about twice that of another (Figs. 2, 3 a). Figs. 2, 3 b are gotten by the oscillograph, while Fig. 2 c is a photogram of the sparks through the series gap taken by the camera with rotating photographic film. One cycle of the curve or every two groups of dots corresponds to 1/60 sec. Fig. 2 c shows apparently that the striated discharge consists of groups of intermittent impulsive currents distributed at regular time intervals. Each dot in similar groups in the photogram is of the same size that is, the same amount of electricity flows in every spark. In the discharge with a very small width of S (such as Figs. 3), the number of sparks in a cycle is very large, but the luminosity of each spark is so feeble that we can hardly reproduce its photograph taken by our lens (F/2). Another fact to be remarked in this cinematograph is that of two consecutive groups of dots one is far superior to the other in the number of dots.

The circumstances are made clearer by the oscillographic observations of the same discharge. We see in Figs. 2, 3 b that almost all of the current is positive (i.e. the positive part corresponds to the superior group above mentioned) and only a very small part is negative. Single impulse in the positive part is not always of the same amount to that in the negative.

Besides, we have tried the striated discharge with some other kind of electric source in order to determine the sense of the discharge. First, the high alternating electromotive force is rectified by means of two kenetrons and then applied to the discharge circuit as usual (Fig. 4). The same figure as that with A. C. source appears on the glass plate if the rectified current be positive to the needle side, while no figure is obtained if the current be reversed.[4] Fig. 5 a is the oscillogram of the electric current while the striated figure is appearing. Fig. 5 b is the form of rectified current when some water resistance is applied instead of the discharge system and the series gap.



K: Kenetron

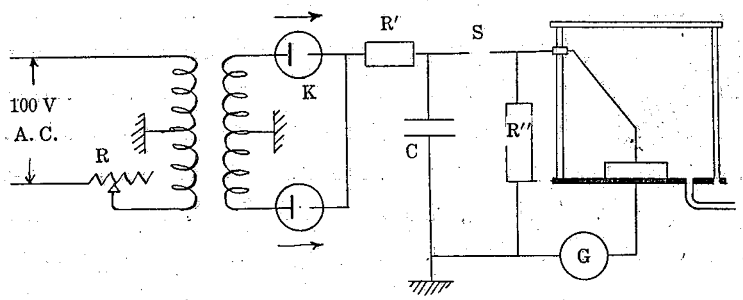
Fig. 4.

Next, with a rectified high electromotive force and a large capacity,[5] we can obtain a similar discharge figure, if the current be positive to the needle side (Fig. 6). The figure thus caused to appear is very fine for naked eyes, but is somewhat unstable especially using glass as dielectric so that the direct photographing of the figure is quite

(4) Previous reports concerning the discharge using a kenetron (Memoirs of the Faculty of Engineering, Hokkaido Imperial University, **1** (1927), 117) and the source of the discharge (loc. cit. **1** (1928), 239; Proc. Imp. Acad., **4** (1928), 17, 286) are somewhat to be corrected by the present researches.

(5) P. O. PEDERSEN: See Handbuch der Physik, Bd. XIV, 395.

difficult, Fig. 7 represents an oscillographic production of this striated discharge, and we see that a large current flows by a single spark under the influence of the capacity.



R′, R″: Water resistances C: Capacity = 0.03 m F.

Fig. 6.

Thus we have determined that the characteristic striated figure is due to the positive and intermittent discharge and that the number of striae, of which the constancy is a chief characteristic of the figure, remains unaltered by different amount of electric flow (positive to the needle side) by a single impulse discharge or by different number of impulses per sec. Of course, the spark gap in the electric circuit plays the necessary rôle for making the high tension electromotive force properly impulsive and appearing the striated figure.

III. RECTIFICATION OF HIGH TENSION A.C. BY THE STRIATED DISCHARGE

The amount of rectification is indicated by an ordinary milliamperemeter, but the detailed state of rectification can be studied by the oscillographic measurement. It is remarkable that the range of the positive current is, as we see in Figs. 2, 3 b, very large (commonly larger than half a cycle).

Fig. 8 a is an oscillogram of the striated discharge keeping the primary current to 2.5 eff. A, while 8 b is obtained by applying a proper water resistance but keeping the primary current and resistance the same as before.

In order to compare different kinds of measurement with one another, firstly, we have assumed that the area drawn in one cycle by a curve made smooth by taking a mean of numerous impulses is proportional to the electric flow, and calculated the mean current.(6) Let the apparent and the absolute mean currents be denoted by I_{m1} and I_{am1}. Secondly, we have measured the mean current I_{m2} by the D.C. milliamperemeter. Thirdly, we have calculated the absolute mean value I_{am2} of Fig. 8 b. Lastly, we have measured the effective value I_{eff} of the same current by a thermo-milliammeter. For example,

I_{m1} (mean of 5 consecutive cycles)	$=1.52$ mA
I_{m2} (by D.C. milliammeter)	$=1.51$,,
I_{am1} (mean of 5 consecutive cycles)	$=1.65$,,
I_{am2} (mean of 5 consecutive cycles)	$=1.63$,,
I_{eff} (by thermo-milliammeter)	$=1.80$ eff. mA
$I_{am3}=I_{eff}\times\frac{.64}{.71}$ (7)	$=1.62$ mA.

They coincide with each other within the probable error of the measurements. Therefore, the oscillographic method is convenient for measuring a very frequent impulsive current such as the present striated discharge.

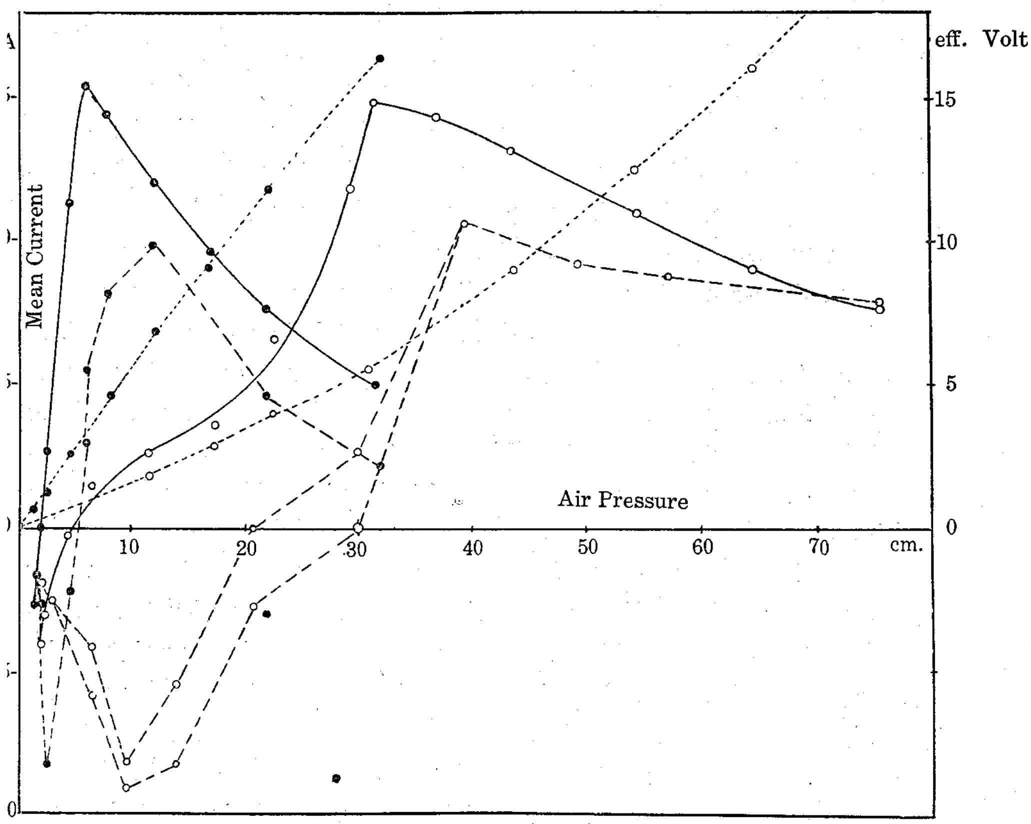
Fig. 9 is an example of the same discharge as above but with no series spark gap (figureless). We see, besides the great change of the mean current, that the negative part is continuous (arc discharge). A part of the positive also often becomes continuous (at low air pressure, say 4 cm.). The continuous part of the curve mentioned is often replaced by a solitary impulse discharge by some different conditions (say, by higher pressure of air or with thicker glass plate, Fig. 10 a being an example). This solitary discharge is quite different with the striated discharge, for example, the electric flow in a single spark is

(6) The area is measured by putting the original film on a paper sected for every 1 mm^2.

(7) H. KADEN. Wiss. Veröffentl. a. d Siemens-Konz Bd. 3, S. 41. 1923.

very large compared with that of the striated discharge, the spark is very luminous, flow takes place along the shortest distance between the electrodes (such is nothing but an ordinary spark discharge).

If in the striated discharge we increase the primary current by reducing the resistance R, some arc or a solitary spark superposes on the striated figure. But the mean current I_{m2} remains nearly the same. The oscillographic investigation shows us that the arc or solitary sparks



Full line : with S 0.025 cm.
Broken ,, : ,, S 0
Dotted ,, : Primary voltage
● : with glass No. 1
○ : without any dielectric plate. (Distance between the point-plate electrodes : 3.5 cm).

Fig. 11.

occur in the negative side of the current (Fig. 10 d). All curves in Fig. 10 are gotten with the glass dielectric called No. II. The phenomena without series gap or with superfluous current are more or less affected by the different sizes of the dielectric, air pressures and intensities of current.

The maximum electric current producing pure striated discharge depends chiefly on the size (or to speak more precisely, on the ratio between the diameter and the thickness) of the circular dielectric.

The mean current-air pressure diagram varies somewhat with different sizes of the dielectric. In Fig. 11, for example, the diagram using No. I as dielectric shows that: the range of the mean current other than zero is much larger than that using No. II, the mean current without series gap varies from negative to positive by increasing air pressures, while that using No. II is always negative.(8)

Lastly, we have constructed, for comparison, a similar current-pressure diagram using the same discharge vessel but without glass between the electrodes,(9) the primary current being kept to 2.5 eff. A always. The existence of a small series gap has a great effect, especially in lower pressures, both on the nature and the mean value of the secondary current. (Figs. 12, 13)

The chief characters of these two kinds of rectifier are compared with one another as follows:

1. The maximum positive current flows at nearly the same air pressure (several cm. Hg) in the striated discharge, but by the point-plate rectifier at much higher pressure, and the maximum point in the latter rectifier is removed rapidly to a higher pressure by decreasing the distance between the point and the brass plate.

2. The mean current using the latter rectifier with series gap is very small at the air pressure at which the characteristic striated figure can be obtained.(10)

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(8) T. Itoh: Proc. Imp. Acad., **5** (1929), 5–8.

(9) The rectification of a high tension A. C. at reduced air pressure by means of "point-disc" electrodes is investigated recently by A. Pochettino and G. Fulcheris (Cim. (N. S.) **5**, 143–166, 1928, No. 5).

(10) The numerical indication given in the foot-note of the previous report (T. Itoh, loc. cit. p. 8) corresponds to the present case.

3. Without the series spark gap, the range of air pressure giving negative rectification is larger in the latter rectifier than in the former.

SUMMARY

Oscillographic researches reveal many characters on the striated discharge as pointed out briefly in the following :

a) The characteristic striated figure is due to a positive, impulsive discharge taking place frequently.

b) The mode of rectification of the high alternating current by means of the striated discharge is extraordinary.

c) Different kinds of discharge are clearly discriminated by the oscillograph.

d) The striated discharge is compared with a point-disc discharge in various points such as kind, rectification, its sense and so on.

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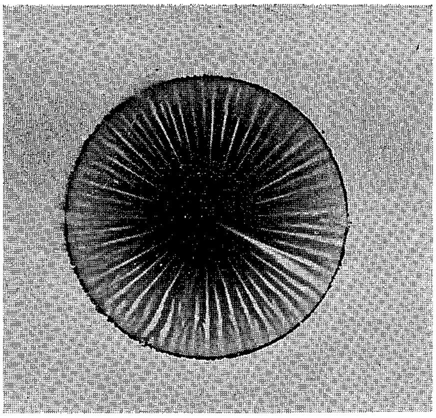
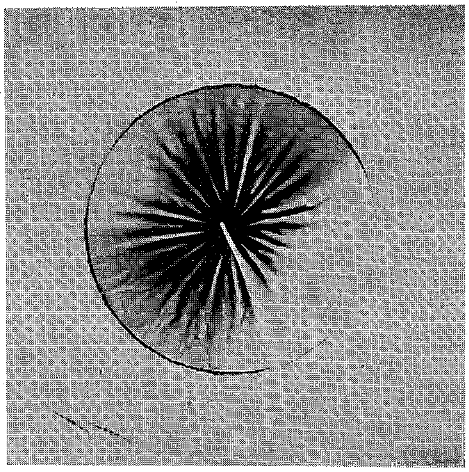


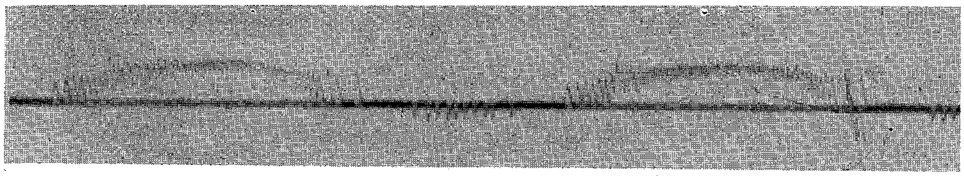
$\times \frac{1}{4}$

Fig. 2 *a*.



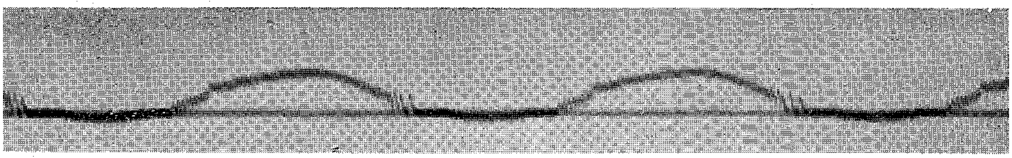
$\times \frac{1}{4}$

Fig. 3 *a*.



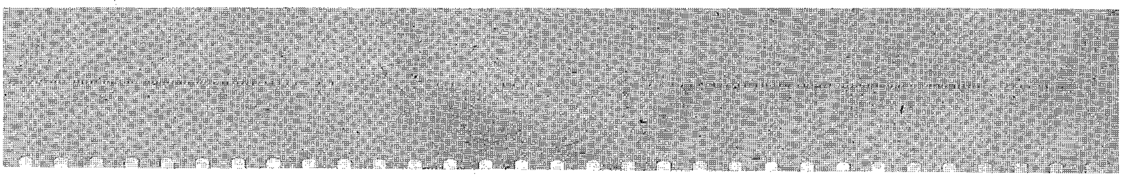
$\longrightarrow t$

Fig. 2 *b*.



$\longrightarrow t$

Fig. 3 *b*.



$\longrightarrow$

Fig. 2 *c*.

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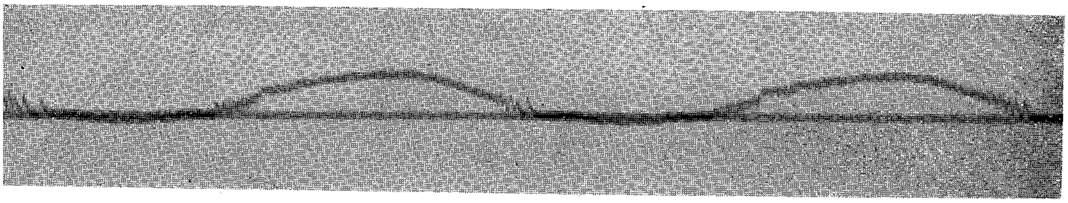
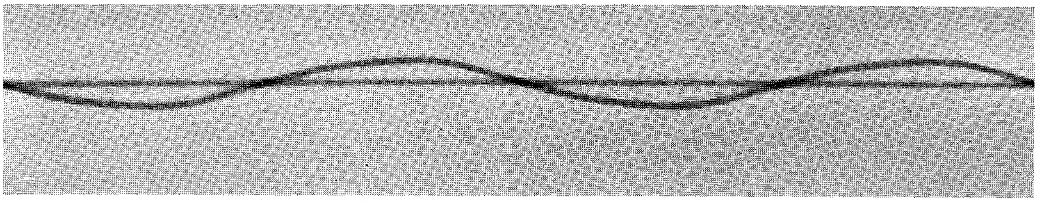


$\longrightarrow t$

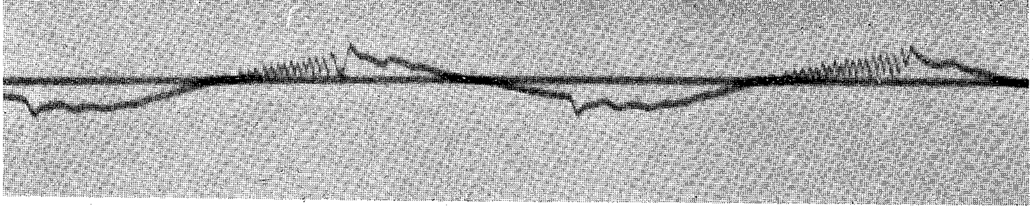
Fig. 8 *a*.

Positive area = 156 mm²
Negative area = 6 mm²



$\longrightarrow t$

Fig. 8 *b*.



$\longrightarrow t$

Fig. 9.

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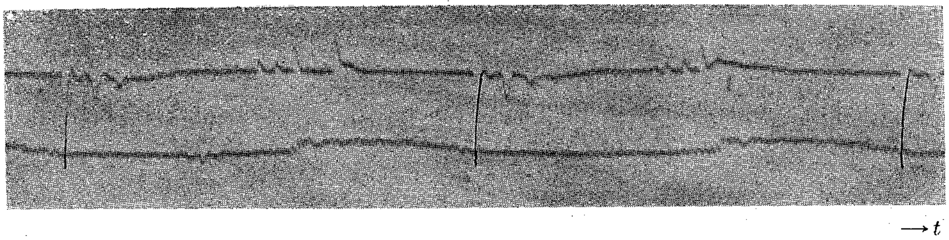

Fig. 10 *a*, *b*.

	P.C.	S.C. (I_{m2})	S	Air press
a	1.0 eff. A	− 0.15 m A	0	7.5 cm
b	1.0 eff. A	+0.41 m A	0.023 cm	7.5 cm

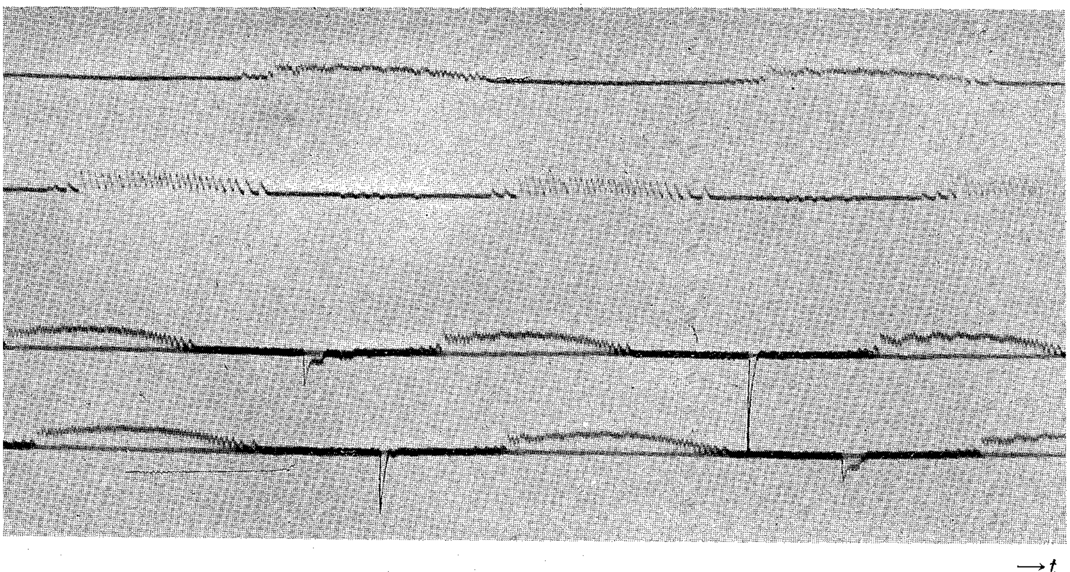

Fig. 10 *b*, *c*, *d*, *d*.

	P.C.	S.C. (I_{m2})	S	Air press
b	0.90 eff. A	.40 m A	.025 cm	7.5 cm
c	0.90 eff. A	.38 m A	.065 cm	7.5 cm
d	1.5 A	.50 m A	.065 cm	7.5 cm

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