Radial Electric Discharge Figure on Dielectric Plate at Low Pressure of Gas.[1]

By

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Introduction.

Many have studied about striated discharge figures which are generated in a glass tube at low pressure of gas under a sufficiently high electromotive force applied on the electrodes. They have investigated this phenomenon (it is known also as "Glimmentladung") chiefly on such points as, the effect of the use of different gases and pressures, the electric field distributions in the discharge tube, Faraday dark space, etc., but the discharge vessels they used are always long and narrow and may be called "discharge tubes."

We know, on the other hand, some discharge figures produced on the surface of a dielectric substance. The well known one among them is the "Lichtenberg figure." The phenomenon occurs however at an ordinary atmospheric pressure and by an instantaneous electromotive force.

Besides, we have recently found the "circular spark," a new class

1) A preliminary report on the finding of this new class of discharge figure was first made at the annual meeting of the Physico-Mathematical Society of Japan which was held on 1 April, 1927, and is also given in our previous essay "Further Researches on the Circular Spark" in this *Memoirs*, Vol. I, p. 117. A short abstract of a part of the present work was published recently in Proc. Imp. Acad. Japan, IV (1928), No. 1, pp. 16-19.

of the form of spark discharge.[1]

The phenomenon we are going to describe in this paper is a peculiar type of electric discharge figure which appears on a dielectric plate at low pressure of gas. The discharge vessel used at present consists of a hollow cylindrical glass having both height and diameter of the same magnitude. The present figure has an appearance something like the negative Lichtenberg figure made on a photographic plate, but they are actually quite different phenomena; they have many characteristics quite different to each other. The figure is rather near to the circular spark in several points as will be shown later.

We observed, about a year ago, a peculiar class of electric discharge figure during our previous experiment on the circular spark under reduced air pressure.[2] The main parts of the apparatus consist of a high voltage testing transformer, a series spark gap and a discharge vessel above mentioned. The vessel contains a needle point electrode, a dielectric plate and a brass plate (which is fitted to the lower edge of the vessel). When a high and alternating electromotive force is applied on the needle point and the members in the electric circuit are properly regulated, a circular spark may appear on the dielectric plate, the centre of the circle being coincident with the needle point. Now if the air pressure is reduced gradually, the circle will be enlarged hyperbolically. But this kind of spark can hardly be observed at one third of an atmospheric pressure.

At an air pressure of several cm. of mercury there appears a peculiar form of discharge figure on the dielectric plate, which first becomes quite obscure and then invisible if the pressure be again reduced to a certain limiting value. This figure however is quite another type of electric discharge than the circular spark.

The apparent differences in characteristic properties between the circular spark and the present discharge figure are that

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1) Y. Ikeda, T. Itoh and S. Kojima, *Proc. Imp. Acad. Japan*, Vol. III. (1927), p. 13, and the same authors, this *Memoirs*, Vol. I. p. 105.

2) T. Itoh, this *Memoirs*, Vol. I. p. 117.

1. the circular spark is a peculiar type of electric sparking discharge, while the present figure is a type of "Glimmentladung" which appears at low pressure of gas,
2. the circular spark is obtained at an ordinary atmospheric pressure, but the present one appears at a reduced gas pressure of several cm. of mercury,
3. the diameter of the circle in one case varies regularly with the thickness of the dielectric plate, while the number of radiating striae (which are a principal characteristic feature of the present discharge figure) is a function of the surface area and the thickness of the dielectric,
4. the potential difference on both sides of the dielectric is much smaller for the present figure than for the circular spark previously studied,
5. the diameter of the circular spark increases hyperbolically with decreasing air pressure, but the number of striae of the present figure remains the same despite variations of gas pressure,
6. the electric current passes through the dielectric plate in the circular spark, while the most part of it flows over the surface of the dielectric in the present case,
7. if the needle point electrode is replaced by that of a plane circular disc, the diameter of the circle in the one case increases by an amount just equal to the diameter of the disc electrode, while the number of striae in the present figure remains unchanged.

There exist, on the other hand, many characters which are very like for both phenomena, namely

1. the principal part of the system on which the phenomenon appears consists, for both cases, of a needle, a dielectric plate and a brass plate all set in the same way,
2. the electromotive force to be applied must necessarily be alternating for both cases,

3. the existence of a spark gap in the electric circuit, in which the discharging system in question is contained, is absolutely necessary for producing the phenomena; the gap plays an important rôle to exhibit and regulate the phenomena,
4. both phenomena are very stable in their positions,
5. the phenomenon is, in both cases, a result due to a certain resonance effect of electric oscillations, etc.

We have recently made some systematic observations about this discharge figure using glass plates and some other dielectric substances, and obtained results described in the following pages.

For the sake of simplicity, we will call the present radial discharge figure the "R figure" hereafter.

Part I. Experimental Investigations of Radial Electric Discharge Figure on Dielectric Plate at Low Pressure of Air.

I. Apparatus and Electrical Connections.

The main part of the apparatus used in the present experiment consists of a cylindrical glass vessel having both diameter and length (height) of about 20 cm., the lower edge of which is soldered to a thick brass plate by means of sealing wax, while the upper is fitted by rubbing to a thick plane glass and is made tight for gas by means of wax. This is the discharge vessel we used. It is set with its axis vertical during the experiment. The dielectric and the needle point electrode are put at the centre of the above mentioned vessel, but the upper part of the needle is lead obliquely into the vessel from outside for convenience in taking photographs of the discharge figure from directly above.

The electrical connections in the experiment are shown diagramatically in the following:

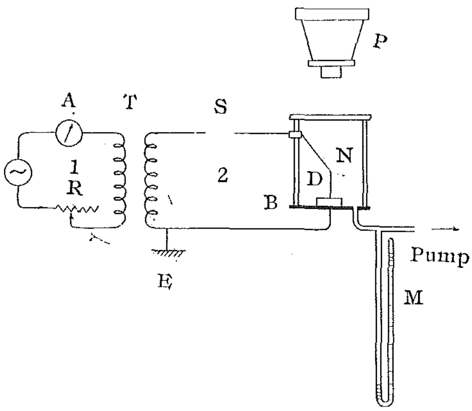


Fig. 1 (I)

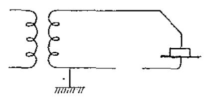


Fig. 1 (II)

1 : Primary circuit
D : Dielectric
B : Brass plate
T : High tension transformer
R : Rheostat
P : Photographic camera
2 : Secondary circuit
N : Needle point electrode
S : Spark gap having conical ends
A : Ammeter
M : Mercury manometer
E : Earthing point

Fig. 1 (II) is another type of electric connection and is shown here merely symbolically. The difference of these two connections is the different positions of the spark gap in the secondary. There exist, beside these two, many kinds of electric connections ; they will however be described later in this essay.

The source of our high and alternating electromotive force is a high voltage testing transformer having a maximum output of 100 K.V. and 50 m.A.

The primary electric current is alternating with a cycle of about 60 per second. The intensity of the primary current and the secondary voltage at the same time are regulated by the rheostat R. The primary voltage at no resistance is 60 volts.

The width of the spark gap is variable at will, and the two ends of the gap are sharp conical. An ordinary spherometer is used for one end of the gap, and the reading of the width of the gap is more accurate than one thousandth of a centimeter.

The vertical portion of the needle electrode in the discharge vessel is a steel sewing needle half a millimeter in diameter and 6 cm. in length having a very sharp point.

Lastly, the form of the dielectric is commonly a circular cylinder, and the axis of the (cylindrical) dielectric is put vertically on the brass plate. The needle point electrode is made to just touch the middle point of the upper surface of the dielectric.

The method of generating the stable R figure is

1. to set, first, the necessary electric connections, and adjust the mutual positions of the needle point electrode and the dielectric plate, paying attention especially to the contact between the brass plate and the lower surface of the dielectric, to the eccentricity of the position of the needle point and to the verticality of the needle,
2. to fit the thick glass plate by means of wax on the upper edge of the cylindrical discharge vessel, and then to pump out the air inside,
3. to apply a high and alternating electromotive force between the needle and the brass plate of the vessel when the air pressure is reduced to several cm. of mercury,
4. to regulate the intensity of the discharge current (rather than the potential difference on both sides of the dielectric) in the vessel by the rheostat in the primary circuit,
5. to regulate the width of the spark gap until a stable R figure appears on the dielectric plate.

Then we may take photographs of the figure by giving exposures of about 10 to 20 seconds at F/4.5 of the photographic objective. We may measure also the width of the spark gap, the manometric height, etc.

II. Effect of Variation of Gas Pressure.

We have investigated the effects on the discharge figure by varying the gas pressure in the discharge vessel wholly with the air at present.

There exists a certain amount of air pressure necessary for obtaining the characteristic discharge figure. The proper pressure is not a single value even for a given dielectric plate, but there exist an upper and a lower limit. In this proper range of air pressure, we can obtain a fine and stable R figure by adjusting and regulating both the width of the spark gap and the intensity of the electric current in the discharge vessel. The figure vanishes altogether at other air pressures, and there occur unsteady and figureless discharges commonly observed in a low pressure discharge.

Besides, there are some regular changes in the features of the figure caused by varying the air pressure. If we reduce the air pressure gradually from the upper limit, with a given dielectric plate, and regulate the members in the electric circuit suitably for each stage of pressure, a few dark canals which are a part of the characteristic feature of a R figure appear first around the needle point. The starting points of the canals then are very close to the needle point. Again at this stage, all over the dielectric surface, except in the dark canals mentioned, appear unsteady and luminous (blue coloured) discharges which may be observed in an ordinary discharge tube at a low air pressure.

As the air pressure is further reduced, the number of dark canals increases soon reaching to a certain definite number, and the canals elongate themselves as far as the edge of the upper surface of the dielectric. The figure at this stage is the most beautiful and typical, and a (certain definite) number of bright striae and dark canals radiate, side by side, with equal angles to each other, from the centre on which the needle point just touches.

If we reduce the air in the vessel further, the striae and the canals appear not only on the upper surface, but also on the cylindrical surface of the dielectric, and they sink each separately in the brass plate. The R figure at this stage is still more stable.

On the other hand, the starting points of the dark canals recede from the centre more and more with decreasing air pressure and finally the striae and the canals are visible only on the cylindrical surface of the dielectric, and the upper surface is coated wholly with a uniform blue brightness. The bright striae, however, broaden themselves gradually with decreasing air pressure, and their boundaries (as well as those of the dark canals) become very vague, when the air pressure is very near its lower limit. The stability of the figure even at this stage is not at all diminished.

The lower limit of the allowable air pressure may be defined as a stage when the striae of the figure, in spite of full regulations of the width of the spark gap and the electric current, become only slightly visible near the edge or on the cylindrical surface of the dielectric. In the sphere of our experiment, the lower limit of the air pressure is, nearly the same for different substances and sizes of the dielectrics, 2 or 3 cm. of mercury.

Fig. 2 is an example of the figures at different air pressures with the same circular glass plate of 10 cm. diameter and 0.163 cm. thickness. Data of this observation are given in Table I.

TABLE I.

No.	Air pressure	Width of spark gap	Electroscopic deflection	Number of striæ	Remarks
1	24.0 cm.	0.017 cm.	—		Unsteady discharge streams.
2	17.5	.020	—	10	Imperfect figure
3	14.5	.046	—	26	R figure corr. I
4	10.8	.046	—	25 or 51	,, I, II
5	8.6	.033	18.0	52	,, II
6	6.0	.026	14.5	26 or 51	,, I, II
7	3.4	.028	7.5	50	,, II
8	3.2	.012	7.7	26	,, I
9	2.5	.038	5.0		,, II
10	<1.8	.034	<3.0		No figure

Dielectric: A circular plate of ordinary window glass having 10.0 cm. dia. and 0.163 cm. thickness.
Discharge vessel: V (I).
Electric connection: Type (I) in Fig. 1.
Temperature: 22° C.
The width of the spark gap is so regulated as to cause the finest figure to appear for each stage of air pressure.
One division of the electroscopic deflection corr. to about 200 eff. volts.

It may be seen from this Table that the potential difference (which is measured by an electroscope connected between the needle electrode and the brass plate) decreases rapidly with decreasing air pressure.

Another and the most important fact in the variation of the air pressure is that the number of striae of the figure remains always the same, if the dielectric and its size are given.

Another example of variations of the air pressure (as well as of the width of the spark gap) with a thick glass plate (consisting of a number of thin sheets of window glass and having 11.0 cm. diameter and 2.5 cm. thickness) is given in Fig. 3.

III. Effect of Spark Gap on the Discharge Figure.

For obtaining the present discharge figure, the existence of a spark gap in the electric circuit containing the discharging system in question is absolutely necessary. (Some gas tubes of low pressure having certain proper qualities can generate, though seldom, a like figure without any spark gap in the circuit.) Besides, the width of the gap for obtaining a fine and stable figure is a certain definite value for any given system and conditions.

Using no gap or a width of the spark gap quite different from the proper value the characteristic R figure vanishes altogether, and discharges, noisy, unsteady in their positions and flowing along random directions, take place.

The spark gap must certainly serve to excite the system in question and to make the figure appear corresponding to the same system. Further, the fineness or the stability of the figure depends on the amount of this excitation or, in other words, on the degree of harmonization between the exciting force and a certain parameter due to the system to be excited. In some cases of the most favourable conditions, the excitation (or the harmonization) reaches its maximum value; that is nothing but a resonance of electric oscillations in the circuit containing the system in question. The occurence of the resonance may be understood firstly by the fineness of the figure appearing, and secondly by the discharge sound which is especially refreshing in the resonanced state.

Again, Fig. 4 is given in order to show roughly the variations of fineness (or stability) and the number of striae of a figure with increasing or decreasing width of the spark gap. The length of the

a. Variation of fineness of the R figure with different widths of gap.

b. Variation of number of striæ of the figure with different widths of gap.

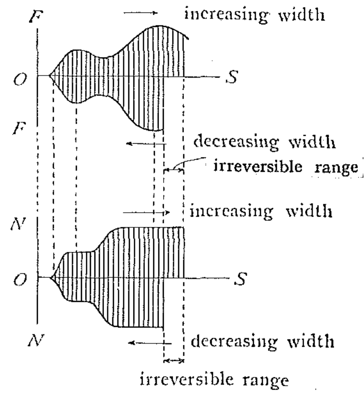


Fig. 4.

ordinate in the diagrams represents roughly the fineness or the number of striae in each stage of the width of the gap. There exist smaller and larger limits for the appearance of the figure, and the latter value varies by increasing and decreasing the width of the gap. The existence of this irreversible range of width of the gap must be due to an inertia of oscillation in the electric circuit under consideration.

Those resonance and inertia effects are very evident with a thick dielectric plate especially when the spark gap is connected between the brass plate of the discharge vessel and the earth. (Fig. 1. (II))

Fig. 5 shows one example of each resonanced and unresonanced states.

With a thin dielectric plate or for an electric connection of another type (say, (I) in Fig. 1), on the other hand, the above effects are not evident and there is no limit at which the figure should vanish suddenly. An example of the figure obtained on a thin glass plate with various widths of the gap is shown in Table II and Fig. 6.

TABLE II.

No.	Width of spark gap	Electro-scopic deflection	Number of striæ	Remarks
1	0.000 cm.	20.0	0	No figure, no stream discharge, dark all over the glass surface, but luminous spots at the needle point and the edge of the glass.
2	.001	14.7	0	No figure, no stream, bright all over the glass surface, a luminous band round the edge of the glass.
3	.009	13.5	23	The R figure corr. to the proper oscillation due to the given system, though not yet perfect.
4	.028	11.0	40	A greater part of the R figure corr. to the second harmonics.
5	.036	10.5	46	The most stable and finest R figure corr. to the second harmonics.
6	.052 .075	9.8 10.5	47 ,,	The same figure as above, but the starting points of the dark canals recede more and more with increasing widths of the gap.
7	.150	8.6		Striae of the R figure are visible only very near the edge of the glass.
8	>.30	<8.3		No striæ, uniformly bright all over the glass.

Dielectric: A circular plate of ordinary window glass 10.0 cm. in dia. and 0.170 cm. in thickness.
Discharge vessel: V (I).
Electric connection: Type (I) in Fig. 1.
Temperature: 24 to 25° C.
Air pressure in the discharge vessel: 4.9 to 5.2 cm. of mercury.
Primary electric current: 0.82 to 0.75 A.
Electroscopic deflection: One division corr. to about 200 eff. volts.

In general:

1. The number of striæ of the R figure does not vary with the width of the spark gap except by a certain special change (which occurs rather suddenly and non-continuously) both in the number of striæ and the feature of the figure. The number of striæ of the figure becomes commonly about double after this peculiar jump.

2. The potential difference between the needle point and the brass plate decreases rapidly with increasing widths of the gap, though there are no appreciable changes of the air pressure in the discharge vessel nor changes of the primary electric current.
3. The starting points of the dark canals of the figure recede more and more from the centre with increasing widths of the spark gap, and at last they come quite out of the glass surface and no striæ are visible. In the case of a thick dielectric, however, the figure suddenly vanishes before the last stage is attained.

IV. Results of Experiments with Glass.

Observations concerning the characteristic radial discharge figure are made with circular glass plates (or circular cylindrical glasses) of various sizes. The glass used at present is ordinary window glass from 0.13 to 0.19 cm. in thickness, and some thick plates are prepared by piling a number of them on top of each other. Thus the glasses used in the present measurements have various sizes from 1.8 to 18.5 cm. in diameter and from 0.13 to 10.0 cm. in thickness of which the larger values are the maximum sizes which can be set in our discharge vessel. The stable radial discharge figures can be generated for all sizes of glass that we have used by regulating and adjusting the width of the spark gap and the air pressure for each case.

The proper width of the spark gap in the electric circuit is different for each glass having different size, but it is always small and commonly less than 0.1 cm. though it must never be zero.

Table III.

Variation of Number of Striæ of the R Figure with Thickness of the Dielectric Plate, its Diameter being kept the same.

No.	Thickness of glass	Air pressure	Width of series gap	Number of striæ I	II	III	IV
1	0.129 cm.	6.9 cm.	0.030 cm.		55		
		4.9	.014	28			
		4.9	.023		52		
2	.185	5.3	.026		46		
		4.0	.018	23			
3	.227	3.5	.017	19			
		3.7	.038		41		
4	.275	4.5	.019		38		
		3.3	.018	19			
5	.348	4.7	.024		33		
		2.9	.021	17			
6	.515	4.2	.045		27		
		4.2	.016	16			
		3.1	.016	14			
7	.675	4.0	.026	11.5			
		3.1	.023		22		
		2.9	.036			38	
8	.900	4.7	.022	10.5		31	
		2.6	.016		21		
9	1.24	5.3	.030	9			
		3.1	.041			26	
10	1.66	5.6	.022	8			
		2.9	.043		16.5	25	
11	2.15	3.5	.038		14		
		5.7	.024	8			
		2.2	.045			20	
12	2.83	6.7	.026	6			
		3.4	.035		12	15.5	
13	3.80	3.7	.040		10	15	
		5.7	.064			15	
		2.2	.045			14	
14	5.02	4.0	.030		9		
		2.8	.056			14.5	
15	6.52	2.4	.054			11	
16	8.42	7.2	.082		7.5		
		3.0	.090				14

Dielectric: A number of circular plates of ordinary window glass each of 10.0 cm. diameter.
Discharge vessel: V (I).
Gas in the discharge vessel: Air.
Electrical connection: Type (II) in Fig. 1.
Temperature: 20 to 23° C.

In the above Table, I, II, etc. in the column of the number of striæ denote R figures which are corresponding each to the proper oscillation, the second harmonics, etc. if we suppose the existence of a peculiar electric oscillation due to the system in the discharge vessel. This remark is applicable also for the following data.

Table IV.

Variation of Number of Striæ of the R Figure with Thickness of the Dielectric Plate, its Diameter being kept the same.

No.	Thickness of glass	Air pressure	Width of spark gap	Number of striæ I	II	III	IV
1	0.142 cm.	5.9 cm.	0.032 cm.		56		
		3.8	.024	28			
2	.165	6.7	.048		51		
		4.7	.028	24			
3	.186	5.8	.033		45		
		3.2	.011	23			
4	.227	5.7	.030		41		
		3.2	.014	20			
5	.262	4.1	.030		40		
		2.9	.032	21			
		3.2	.016	19			
		3.4	.032		38		
6	.333	4.4	.054		34		
		3.3	.034	18			
		2.4	.020	17.5			
		3.5	.032		33		
7	.395	3.4	.042			46	
		2.9	.019	16			
		3.5	.044			46	
		2.2	.032		32		
8	.496	2.8	.019	14			
		2.8	.037		32		
9	.628	3.8	.020	12.5			
		3.0	.042			38	
10	.820	3.2	.042		22	32	
		4.0	.021	14			
11	1.050	3.7	.034	12	19		
		2.3	.056			29	
12	1.325	3.9	.027		18		
		3.2	.046			28	
13	1.745	4.0	.030		13		
		2.9	.058		15.5		31
14	2.23	3.9	.082			20	
		2.8	.056			20	
15	2.90	2.9	.076			18	
		3.8	.032		12		
16	3.65	4.1	.116				21
		6.0	.022		10		
		5.9	.067			15	
17	4.68	3.9	.208				20
		4.9	.030		9.5		
		5.2	.080			13.5	
18	5.88	7.1	.094			12.5	
		3.6	.024		8.5		
		4.3	.30				17

TABLE IV. (continued).

No.	Thickness of glass	Air pressure	Width of spark gap	Number of striæ I	II	III	IV
19	7.34 cm.	3.8 cm.	.206 cm.				15.5
		8.0	.050			10.5	
		7.5	.016		7.5		
20	8.84	5.3	.080				13
		8.5	.092			10	
		5.1	.084				13

Dielectric: A number of circular plates of ordinary window glass each of 10.0 cm. diameter.
Discharge vessel: V (I).
Gas in the discharge vessel: Air.
Electrical connection: Type (I) in Fig. 1.
Temperature: 20 to 22° C.

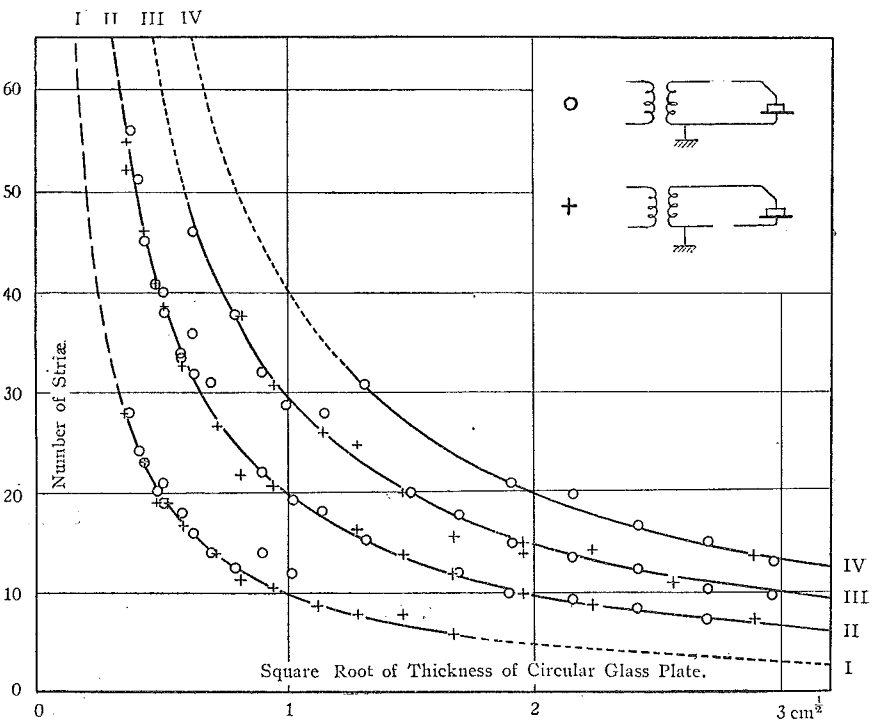


Fig. 7.

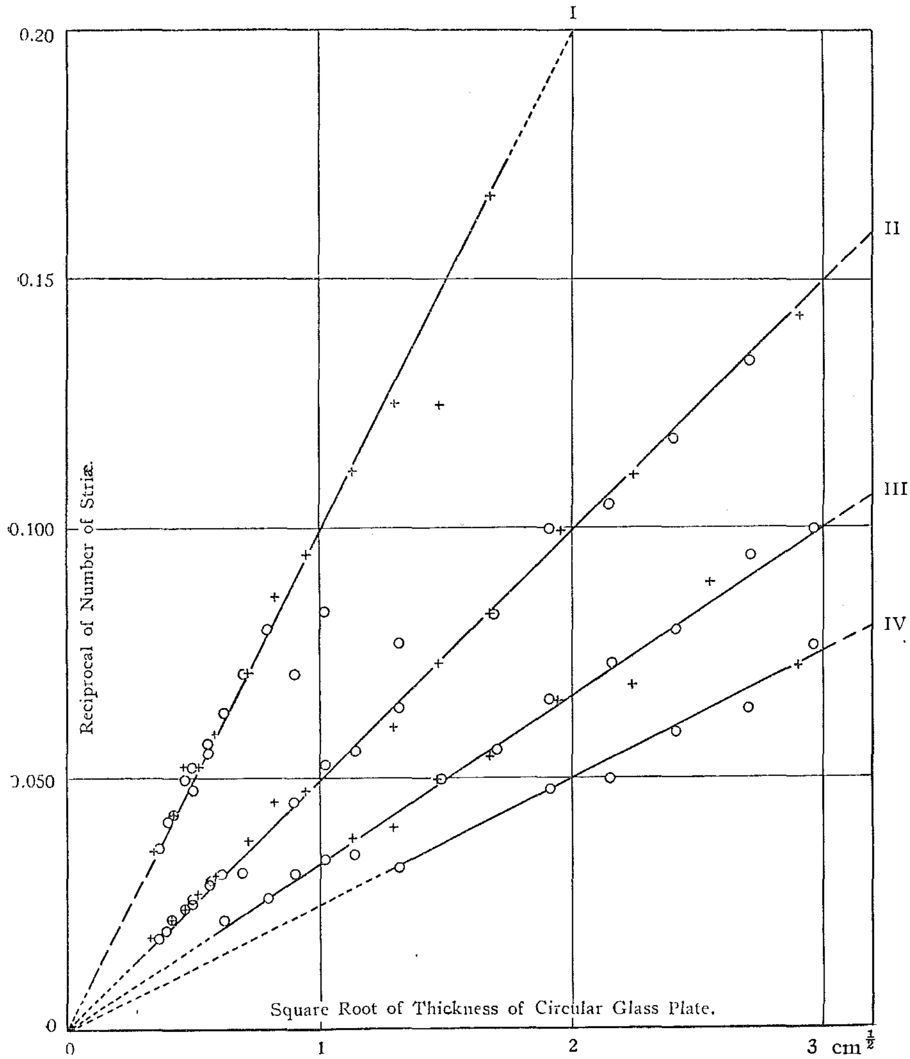

I
II
III
IV
0.20
0.15
0.100
0.050
0
Reciprocal of Number of Striæ.
Square Root of Thickness of Circular Glass Plate.
0
1
2
3 cm$^{\frac{1}{2}}$

Fig. 8.

TABLE V.

Variation of Number of Striæ of the R Figure with Diameter of the Dielectric Plate, its Thickness being kept the same.

No.	Diameter of glass plate	Thickness of glass	Air pressure	Width of spark gap	Number of striæ	
					I	II
1	18.5 cm.	0.170 cm.	4.0 cm.	0.028 cm.	41	
2	17.0	.162	4.5	.028	37	
3	15.0	.185	3.2 5.1	.019 .045	33	65
4	14.0	.160	4.1 4.4	.017 .041	32	64
5	13.0	.170	4.6 3.7	.037 .016	30	55
6	12.0	.160	4.0	.031		52
7	11.0	.169	4.5 4.7	.018 .030	25	48
8	10.0	.166	4.8	.027		46
9	9.15	.165	3.7 3.8	.016 .018	21	39
10	7.95	.162	4.0	.019		36
11	7.0	.166	5.3	.040		25
12	6.3	.165	4.2	.018		28
13	5.2	.165	3.8 4.5	.022 .016		23 21

Dielectric: A circular plate of ordinary window glass.
Discharge vessel: V (I).
Gas in the discharge vessel: Air.
Electrical connection: Type (II) in Fig. 1.
Temperature: 20 to 22° C.

Table VI.

Variation of Number of Striæ of the R Figure with Diameter of the Dielectric Plate, its Thickness being kept the same.

No.	Diameter of glass plate	Thickness of glass	Air pressure	Width of spark gap	Number of striæ		
					I	II	III
1	4.1 cm.	0.176 cm.	8.5 cm.	0.030 cm.		17	
			5.3	.020			27
2	5.0	.161	6.3	.018		23	
			3.7	.018		24	
3	6.0	.172	8.5	.030			40
			7.2	.028		24	
			4.6	.022			39
4	7.0	.163	4.9	.030		30	
			6.0	.018	16		
			4.6	.018		33	
5	8.0	.178	4.0	.032		36	
			3.3	.011	20		
6	9.1	.171	5.7	.030		41	
			3.5	.016	20		
7	10.0	.173	5.5	.030		46	
			3.7	.014	22.5		
8	11.0	.173	4.9	.051		51	
			4.3	.019	26		
			2.0	.019	25		
			4.6	.044		49	
9	12.05	.166	4.8	.044		53	
			3.4	.025	27		
10	13.0	.168	5.7	.050		58	
			3.5	.020	30		
11	14.1	.160	4.6	.062		64	
			3.3	.033	34		
12	15.0	.177	3.2	.024	34		
			5.3	.081		68	
13	17.0	.173	5.2	.104		71	
			3.3	.033	38		
14	18.5	.174	2.7	.033	42		

Temperature: 20 to 23° C.

Dielectric: A circular plate of ordinary window glass.

Discharge vessel: V (I).

Gas in the discharge vessel: Air.

Electrical connection: Type (I) in Fig. 1.

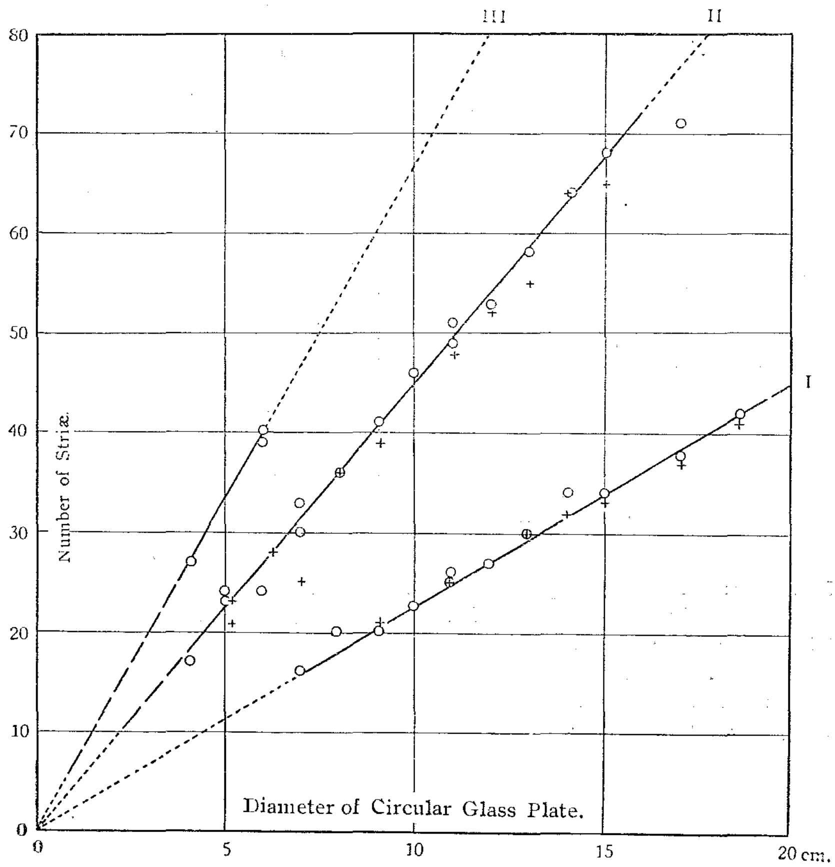


Fig. 9.

TABLE VII.

Variation of Number of Striæ of the R Figure with Diameter of the Dielectric Plate, its Thickness being kept the same.

No.	Diameter or glass plate	Air pressure	Width of spark gap	Number of striæ I	II	III
1	18.6 cm.	4.0 cm.	0.028 cm.	20		
		2.9	.032		40	
2	17.0	4.2	.023	19		
		2.6	.039		38	
3	15.0	4.6	.028	16.5		
		3.1	.033		34	
4	14.0	6.5	.024	14		
		3.8	.038		31	

TABLE VII (continued).

No.	Diameter or glass plate	Air pressure	Width of spark gap	Number of striæ I	II	III
5	13.0 cm.	3.5 cm.	.035 cm.		29	
		7.2	.030	15		
6	12.0	3.7	.015	12		
		4.0	.031		26	
7	11.0	6.7	.068		24	
		3.5	.020	12		
8	10.0	3.5	.023	11	21	
		4.5	.020	11		
9	9.1	5.7	.057		15	
		4.0	.30		15	31
10	8.0	3.4	.035		18	
		2.0	.021		18	
11	7.0	3.9	.019		16	
		2.5	.028			24
12	6.0	4.1	.021		13	
		2.3	.022			18
13	5.0	3.2	.026			17
		3.1	.016			17
14)°	4.1	5.3			9	
		5.1				13

Dielectric: Circular glass plates each consisting of 4 sheets of ordinary window glass. Thicknesses of the plates = 0.70±0.01 cm.
Discharge vessel: V (I).
Electric connection: Type (II) in Fig. 1.
——)°: Electrical connection of type (I) in Fig. 1.
Temperature: 19 to 22°C.

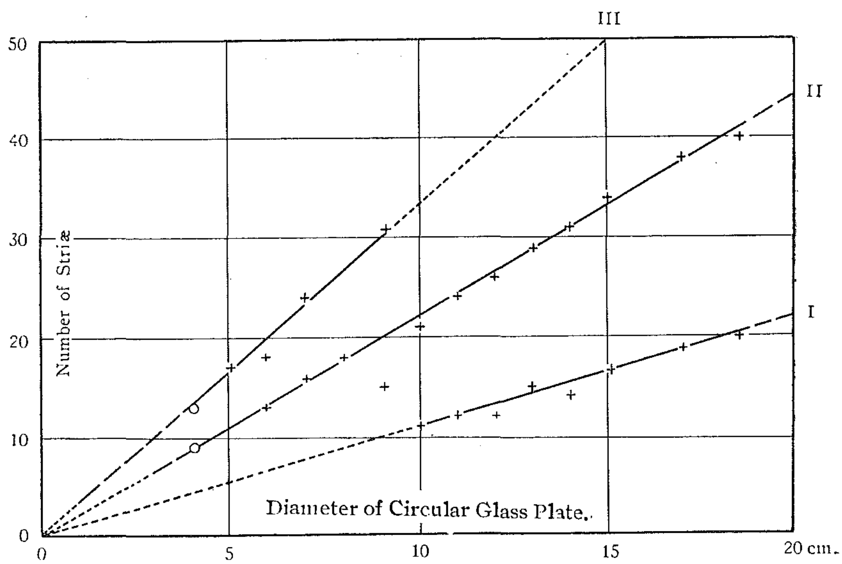


Fig. 10.

The above Tables and Figures tell us the following:

1. If the dielectric (glass at present) and its size are given, the number of striae of the discharge figure generated on its surface is the same for two kinds of different electric connections relating to the position of spark gap, though the figure for (I) type is generally more stable than the other for (II) type connection. Accordingly, the variations of the number of striae of the R figure caused by different sizes of glass plate are the same for these two kinds of electric connection.
2. The most remarkable fact in the result of the present experiment is that
   (a). for a given glass plate, there exist two (or sometimes more than two) kinds of radial discharge figure which are quite different from each other,
   (b). the number of striae of one of these two figures is just twice the other (or the ratio of the numbers of striae is very simple such as one to three or two to three).

   If we suppose the phenomenon to be due to an excited effect on the system or a resonance effect of oscillations in the electric circuit, one of the above two figures may well be considered to correspond to the second harmonics of oscillation proper to another figure. Later we will discuss these relations precisely. (Fig. 11).
3. The above different kinds of figure with the same size of glass can be obtained chiefly by regulating the width of the spark gap and next by varying the air pressure in the discharge vessel. The width of the gap suited for generating the stable R figure corresponding to the higher harmonics is generally much larger than that of the figure corresponding to the proper oscillation.
4. The number of striae of the radial figure decreases hyperbolically with the square root of the thickness of the glass plate, when its diameter (if the glass plate be circular) is kept

same. The diagram representing these relations consists of rectangular hyperbolas which have a common origin on the zero point of the coordinates and have such regular intervals to each other that the ordinates of the second, third, etc. curves are just twice, thrice, etc. that of the first curve. We see these relations well in Fig. 7. (Tables III, IV).
Consequently, a diagram showing the relation between the reciprocal of the number of striae and the square root of the thickness of glass consists of straight lines which pass through the origin and have regular inclinations to each other (or, more precisely, the ordinates of the second, third, etc. lines are just a half, one third, etc. that of the first line) when the diameter of the circular glass plate is kept the same. Fig. 8 shows the relation.

5. The number of striae of the radial discharge figure increases with the diameter of the circular glass plate when its thickness is kept the same. The diagram showing this relation consists of straight lines which pass through the origin and have such regular inclinations to each other that the ordinates of the second, third, etc. lines are just twice, thrice, etc. that of the first line. (Tables V, VI, VII, Figs. 9, 10).
6. For a thick glass of small diameter, the radial discharge figure corresponding to the proper oscillation does not appear (or the suitable width of the spark gap for obtaining this figure might probably be negative), and only some figure corresponding to the higher harmonics appears. The R figure generated on such glass (narrow cylinder) is very beautiful and has thin and clean bright striae. Some photographs of this kind of radial discharge figure are given in Fig. 12.

V. Effect of Different Kinds of Electric Connection on the Radial Discharge Figure.

The most convenient methods of determining the locality of the present discharge figure are to repeat the experiment, with the same dielectric plate, by varying

i. the source of the high and alternating electromotive force,

ii. the discharge vessel,

iii. the air pressure, the intensity of the electric current, the width of the spark gap, etc.,

iv. electric connections,

and to measure

v. the frequency of the electric oscillation to which the radial discharge figure corresponds, if such oscillation exists.

The effects of the third kind of variation have been mentioned already, and we are going now to describe the fourth of the above effects.

If the source of the high electromotive force is a transformer or an induction coil, the chief part of the electric connection for generating the R figure is of course the secondary circuit, and the possible members comprising it are

(1): the system in the discharge vessel,

(2): the secondary of the transformer,

(3): the earthing point or without earthing,

(4): a series or a parallel spark gap,

(5): such that are not absolutely necessary, namely

A: a series or a parallel spark gap,

B: a resistance (low pressure gas tubes)

C: a capacity,

D: an inductance,

E: a stretched conducting wire of which one terminal is to be left free.

When we choose (1), (2), (3) and (4) in the above members there exist 15 possible kinds of connection, if we choose (1), (2), (3) and one of (5) there are about 78 possible kinds, and if we prefer (1), (2), (3), (4) and one of (5) there are indeed more than 300 kinds. These different kinds of electric connection are, on the other hand, classified in three or five types relating to the position of each member. The 11 kinds of fundamental electric connection are given as examples in the following Fig. 13.

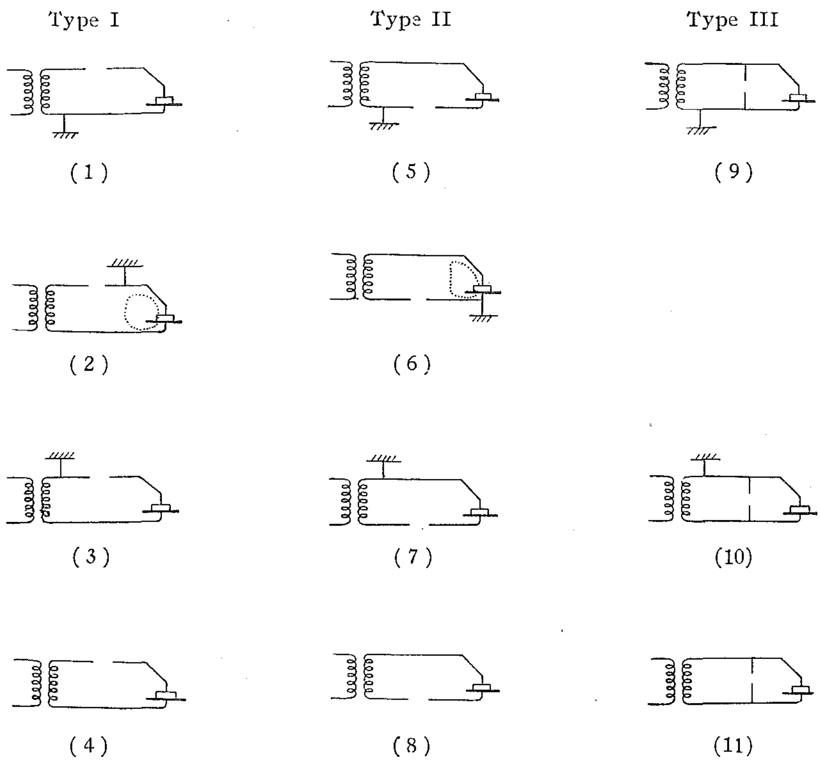


Fig. 13.

In the earlier part of our experiments the electric connection of type II, (5) is used, and afterwards the type I, (1) is used, for the latter always generates a more stable R figure than the former.

Observations are now made for the above 11 and some other more complex kinds of electric connection with the same dielectric plate which consists of nine sheets of ordinary window glass combined to form a circular plate of 10.0 cm. diameter and 1.50 cm. thickness.

The results of the observations are as follows:

(i). Members of the Secondary: (1), (2), (3) and (4).

TABLE VIII.

R Figures for 11 Kinds of Electric Connection.

Electric connection	Air pressure	S, width of spark gap	Number of striæ	Remarks
I, (1)	4.4 cm.	0.059 cm.	17	A stable and very fine characteristic R figure appears. Fig. 14. (1)
(2)				No figure, no striae; unsteady blow discharges from the needle point all over the dielectric surface.
(3)	4.5	.035	16	A char. R figure, beautiful and quite stable. A pleasant discharge sound caused by resonance is heard. (2)
(4)	5.0	.038	16	R figure, even more stable than (1). (3)
II, (5)	5.0 5.2	.040 .005	16 9	A char. R figure, but somewhat less stable than (1). (4). (5)
(6)	4.6	.092		A figure, very poor and quite unstable. (6)
(7)	4.4	.068	17	R figure, more stable and beautiful than (5). (7)
(8)	5.2	.042	16	R figure, the most stable and the finest of II. (8)
III, (9)	5.0	.094	17	A fine and stable figure, having thin and very clean bright striae which vanish suddenly on their way, on a circle concentric with the dielectric plate. (9)
(10)	5.6	.085	18	Ditto, but more stable. The left lower quarter of the figure shown in the photograph is due to the third harmonics. (10)
(11)	3.0	.054		Ditto, the most stable and finest of III. (11)

Dielectric: Nine sheets of ordinary window glass combined to form a circular plate of 10 cm. dia. and 1.50 cm. thickness.
Gas in the discharge vessel: Air.
Temperature: 20 to 24°C.

The chief properties obtained by the above experiment are as follows:

i. The number of striae of the R figure is not altered by different connections.

ii. A characteristic R figure is also generated for the connection having a parallel spark gap similar to that having a series gap, but there are some difference between the two in the appearance of the figure.

iii. The stability or the fineness of the figure is more or less affected by different earthing points or without earthing. The figure obtained without earthing is commonly more beautiful than the others.

iv. For the connections (2) and (6), we can obtain no R figure or a R figure which is quite unstable and very poor; for, the spark gap is excluded, by the earthing point, from the effective oscillation circuit as shown by a dotted line in Fig. 13, (2), (6). Thus a spark gap must necessarily exist in the circuit of electric oscillation for causing the appearance of a characteristic R figure.

(ii). Members of the Secondary: (1), (2), (3) and one of (5).

Some like observations are made with the same glass plate for connections having, in place of the spark gap, a resistance, a capacity, an inductance or a stretched conducting wire. The five types of connection concerning the position of each of the mentioned members are shown diagrammatically below:

TABLE IX.

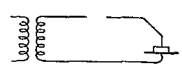
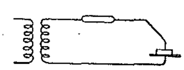
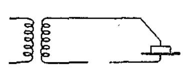
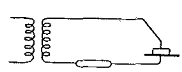
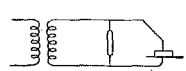
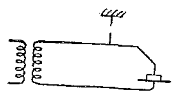
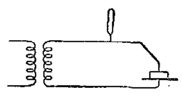
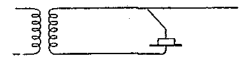
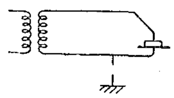
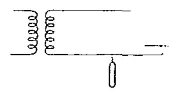
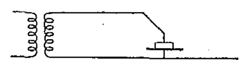
Member / Type	A: A spark gap	B (C, D): A resistance (a capacity, an inductance)	E: A stretched wire
I	 (4 kinds for diff. earthing points)	 (4 ,,)	
II	 (4 ,,)	 (4 ,,)	
III	 (3 ,,)	 (3 ,,)	

TABLE IX (continued).

Member / Type	A: A spark gap	B (C, D): A resistance (a capacity, an inductance	E: A stretched wire
IV	 (2 ,,)	 (4 ,,)	 (3 ,,)
V	 (2 ,,)	 (4 ,,)	 (3 ,,)
	15	+19 (+19+19)	+6=78 kinds.

Experiments are made for the above different connections of electric circuit using the same glass plate, and their results are given in the following:

For most of the connections of the first column A in the preceding Table, one can obtain fine, stable R figures (as already described). For the connection A (IV or V), however, one cannot obtain the R figure, though the discharging appearance then is somewhat different than that of the connection having no spark gap.

For the connections of B where some tubes of low pressure gas are connected as a resistance, one could not obtain the R figure but for a few cases given below:

TABLE X.

Electric connection	Air pressure	Remarks
B (II)	3.3 cm.	A char. R figure, not fine, accompanied by a localized, bright discharge stream. Fig. 14, (12)
B (I)	4.2	Ditto, but more stable than the preceding. (13)
Ditto, but without earthing	4.4	Ditto, but accompanied by no discharge streams as are seen in the above. (14)

Discharge vessel: V (I).
Dielectric plate: As in Table VIII.
Temperature: 20-23°C.

For the other electric connection C (I, II, III, IV or V), D (I, II, III, IV or V) or E (IV or V), one can obtain no figure at all.

We see from the results of the experiment that a certain proper resistance is necessary for producing a characteristic R figure, and such a resistance serves, like a spark gap, as an exciter of generating the figure. Therefore we may obtain a somewhat more beautiful R figure if we can apply more suited resistances.

For the connections of C where a condenser consisting of two circular brass discs both of 25 cm. diameter and a plane glass of 0.17 cm. thickness between the discs is connected in the circuit, no figures are obtained. Using however an air condenser consisting of two circular discs of 10 cm. diameter and regulating the distance between the discs, we can generate similar fine R figures as in the cases having a spark gap. It may be of no use to say that sparks must occur between the discs for bringing about the appearance of the figure. Thus a condenser of small capacity acts just like a spark gap.

For D where an inductance from 10 to 100 milihenries is connected, or for E where a stretched copper wire of about 12 meters is connected, the author can obtain no figures at all.

In short, we see that a spark gap or something which acts like a spark gap must necessarily exist in the electric circuit in order to generate the characteristic radial discharge figure.

We have made some observations besides the above, with the same glass plate, using different connections having more members than the preceding, and obtained various results. Some of them being worthy of remark are shown in the following:

(iii) Members of the Secondary: (1), (2), (3) and Two Spark Gaps.

TABLE XI.

Connection	Air press.	S_1	S_2	Remarks
	cm.	cm.	cm.	
A (I) and A (I)	6.0	0.028	.030	After generating the R figure by one of the two gaps keeping the width of the other zero, let the latter increase gradually from zero, then the figure soon becomes quite unsteady, but if it reaches very near the width of the first gap the initial stable figure will be recovered. Fig. 14, (15), (16)
	{Disch. vessel V (II)}			
	4.7	.020	.020	
	{	,,	V (I) }	
A (II) and A (II)	4.0	.021	.02	Same as in the case having a single spark gap. (17)
	{	,,	V (II)}	

TABLE XI (continued).

Connection	Air press.	S_1	S_2	Remarks
A (I) and A (II)	cm. 4.7	cm. .018	cm. .02	An unsteady R figure; each gap disturbs the figure which results from the use of only one gap. (18)
	{Disch. vessel V (I)}			
A (I) and A (III)	5.4	.034	.10	R figure, same for the case having S_1 only, and still more stable and finer. (19)
	{	,,	V (II)}	
	6.0	.042 {Ditto}	.04	R figure, which is due to S_1, but much disturbed by S_2. (20) If S_2 is very small compared to S_1, a figure due to S_2 will appear.

Dielectric plate: As in Table VIII.
Temperature: 20-23°C,
S_1 and S_2: Spark gaps having sharp conical ends.

The first case of the above suggests the existence of a certain resonance of electric oscillations in the circuit.

(iv) Members of the Secondary: (1), (2), (3), (4) and a Resistance.

TABLE XII.

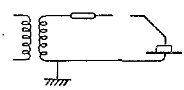
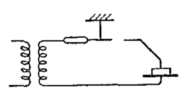
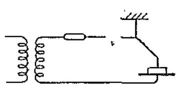
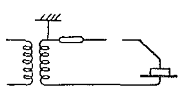
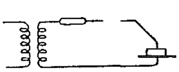
Connection	Air press.	Gap	Remarks
A (I) and B (I) 	cm. 4.4	cm. 0.116	A stable R figure, radiating and very luminous streams superimpose on each stria of the figure. Fig. 14, (21)
			A fine and stable R figure, not at all affected by the resistance.
			No figur, no stria. Unsteady discharge streams radiate on all sides from the needle point, same for the case of no gap.
			No figure; unsteady, radiating discharge streams.
			Like the first case, but the figure is much less fine.

TABLE XII (continued).

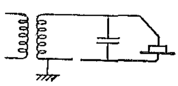
Connection	Air press.	Gap	Remarks
A (I) and B (I) (other connections than the above) A (I) and B (II) A (II) and B (I) or B (II)			Like each of the above.
A (I) or A (II) and B (III)	cm. 5.1	cm. .039	A stable and fine R figure; the resistance has no effect. (22)
Ditto, but with Air and He tubes.	5.0	.008	R figure corr. to the proper osc., stable, but not very fine. (23) R figure corr. to the second harmonics is very faint, for only little current should flow through the gap (the width of which must naturally be larger than that corresponding to the proper osc.)
Ditto, but with Air tube only.			No figure.
Other connections.			Results like the above.
A (III) and B (I)	3.8	.106	A char. R figure due to the series resistance, somewhat refined by the spark gap. (24)
A (III) and B (III)	5.0	.050	A stable and fine R figure; the resistance has almost no effect. (25)

Dielectric plate: As in Table VIII.
Discharge vessel: V (I).
Temperature: 20–23°C.

In short, the characteristic figure due to the spark gap appears if the effect of the unsuited resistance in the circuit is small, but if that effect is large, unsteady R figures appear or figureless discharges take place. For special and favourable cases where there is a resistance just suited to the given conditions or the resistance is excluded from the effective circuit, the characteristic R figures should be generated.

(v). Members of the Secondary: (1), (2), (3), (4) and a Capacity.

TABLE XIII.

Electric connection	Distance betw. discs of condenser	Air pressure	Width of spark gap	Remarks
A (I) and C (II)	cm. 0.17	cm. 4.1	cm. 0.041	A stable and fine R figure, accompanied by a local dischcrge stream. Fig. 14, (26) Intense blow discharges occur betw. the plates of the condenser, emitting a pleasant tuned sound.
	1.00	4.2	.045	A similar figure to the above, but slightly less stable. (27) Sparking blows from all the margins of the plates of the condenser, emitting a noisy sound.
A (I) and C (I), A (II) and C (I or II)				Similar to the above.
A (I) and C (III)	.17	5.1	.041	R figure, most beautiful and quite steady, just obtained by a resonance. (28) Intense blow discharge at the condenser, emitting a clear tuned sound.
	1.00	5.4	.035	R figure, quite stable and the most beautiful of all. No surface discharges at the condenser. (29)
A (I) and C (III) (another than the above)	.17	3.2	.170	A stable R figure, having knots on each bright stria. (30) Very intense surface discharges take place at the condenser.
A (II) and C (III) 				No figure, unsteady discharges.
A (II) and C (III) (another than the above)	.17	4.0	.054	R figure, very faint, accompanied by a very intense local discharge. (31)
A (III) and C (I, II or III)	.17 .17	4.6 4.7	.079 .034	R figures, fine and stable. (32), (33)
	.17 .17	5.2 5.3	.050 .074	Ditto; the capacity seems to have no effect. (34), (35)
	.50	5.9	.102	A stable and fine R figure; its bright striae are very broad compared to that without the capacity. (36)
	.17	3.7	.112	Like figure, but quite faint and unstable. (37)
	.40	3.8	.10	A stable and beautiful R figure, the bright striae are especially broad. (38)

Dielectric plate: As in Table VIII.
Discharge vessel: V (I)
Temperature: 20-23°C.
Capacity: It consists of two circular brass plates both 25 cm. in diameter, with an ordinary window glass 0.17 cm. in thickness inserted between the plates.

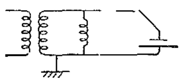
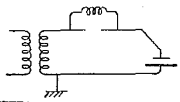
For the cases having a local discharge stream besides a characteristic R figure, if the electric current be weakened, the R figure itself should naturally become faint, but the local discharge stream will never vanish.

(vi). Members of the Secondary: (1), (2), (3), (4) and an Inductance.

TABLE XIV.

Electric connection	Inductance	Air pressure	Width of spark gap	Remarks
A (II) and D (I or II)	mH. 100	cm. 4.0	cm. 0.100	R figure, very faint, luminous streams of ordinary discharge being superposed on each stria of the figure. Fig. 14, (39)
	100	4.0	.010	R figure corr. to the proper oscillation. (40)
	10	4.3	.010	R figure, stable. (41)
	10	4.3	.058	R figure, accompanied by unsteady discharge streams on each stria of the figure. (42)
Ditto, but their relative positions are different.	100	4.7	.016	A fine and stable R figure corr. to the proper oscillation. (43)
	100	5.9	.064	A fine figure corr. to the second harmonics, accompanied by short luminous streams on each stria of the figure. (44)
				The inductance is of use to generate the fine figure corr. to the proper oscillation, but disturbs more or less the figure corr. to the second harmonics.
A (I) and D (I or II)				Fine R figures, not affected by the inductance.
A (I or II) and D (III)	100	4.0	.050	R figure, very beautiful and quite steady; bright striae narrow and clean. (45) Discharge sound at the spark gap is high but small.
	10	4.3	.067	A beautiful and stable R figure; bright striae however are much broader than normal. (46)
				As the inductance decreases from 100 to 10 mH., the bright striae of the R figure become broader and the discharge sound at the spark gap louder.

TABLE XIV (continued).

Electric connection	L, Inductance	Air pressure	Width of spark gap	Remarks
				No discharge, no figure.
				No figure; unsteady discharges.
A (III) and D (I or II)	mH 100	cm. 6.1	cm. .100	R figure, very fine and stable; the bright striae are very thin and clear and vanish suddenly on a circle. (47)
	100	4.4	.064	Ditto, but the bright striae are somewhat broader and very short in length. (48)
	100	6.0	.122	A poor and unstable figure, much disturbed by the inductance. (49)
A (III) and D (III)				No figure.

Dielectric plate: As in Table VIII. Discharge vessel: V (I).
Temperature: 20 to 23°C. Inductance: Variable from 10 to 100 milihenries.

(vii). Members of the Secondary: (1), (2), (3), (4) and one of (5).
(Connections of IV and V types)

TABLE XV.

Connection	Remarks	
	R, D or E earthed	B, D or E not earthed
A (I or II or III) and B (IV or V)	4 tubes connected parallel have almost no effect. A resistance of a few megohms connected to a point betw. the system and the gap disturbs the R figure exceedingly.	No effect of the resistance.
A (I or II or III) and C (IV or V)	The capcity (Distance betw. the discs: 0.17 cm.) connected as above disturbs the figure.	No effect of the capacity, but one exception as shown below: Capacity: 0.17 cm. Air press.: 4.0 cm. Gap: 0.031 cm. A char. R figure, more stable and finer than that without the capacity, and just like the figure to be generated by the A (I) type. Fig. 14, (50)
A (I or II or III) and D (IV or V)	The inductance (10 to 100 mH) connected as above disturbs the figure very much.	No effect of the inductance (10 to 100 mH.)

Dielectric plate: As in Table VIII. Discharge vessel: V (I).
Temperature: 20 to 23°C. Resistance, capacity and inductance: Same to those described in the above Tables.

TABLE XVI.

Effect of a Stretched Conducting Wire.

Electric connection	Length of wire	Air pressure	Width of gap	Remarks
	m.	cm.	cm.	
A (I or II) and E (IV)	12	5.5	0.060	R figure, having some different features, affected a little by the wire. Fig. 14, (51)
	12	5.4	.072	No figure, quite disturbed by the connected wire. (52)
	12	4.1	.086	A fine and stable R figure, not at all affected by the wire. (53)
A (I) and E (V)				No effect of the stretched wire.
A (II) and E (V) (not earthed)				R figure, no effect of the wire (of 12 m. length).
A (II) and E (V) (earthed)	4	5.9	.050	No figure, unsteady discharges. (54)
	4	5.9	.012	R figure corr. to the proper oscillation, but quite unstable. (55)
	2 2	5.0 3.8	.003 .032	R figures, corr. to the proper and the second harmonics of oscillation, but very poor. (56), (57)
Ditto, but with a very thin copper wire of 0.030 cm. dia.	4 4	5.7 5.7	.008 .062	Quite like the case with the thick wire. (58), (59)
A (III) and E (IV or V)				No effect of the wire.

Dielectric plate: As in Table VIII.
Discharge vessel: V (I).
Temperature: 20 to 23°C.
Stretched wire: Circular copper wire of a uniform section of 0.145 cm. dia.

The cause of the above described effects obtained by using a stretched conducting wire connected at one end is not clear. It seems however that the length of the wire which just disturbs the generation of a stable R figure (though it may be very difficult to determine the limiting length of the wire) should have certain relations to the wave length of the electric oscillation which corresponds to the figure, but further investigations must be made for a fixed solution of this problem.

Lastly, all the results of the observations described in the present section show us one important fact which is common to all kinds of different electric connection allowable for generating a characteristic radial discharge figure. It is nothing but a constancy of the number of striae of the figure despite the fact that the features of it are sometimes very different from one another. We see in the preceding photographs given as examples that the numbers of striae are

i. 8 or 9 for R figures corresponding to the proper oscillation,
ii. 16 or 17 for R figures corresponding to the second harmonics of oscillation.

Yet there are a few figures whose numbers of striae are more than 17, which appears to be due to the circumstance that both the second and third harmonics of oscillation due to the system in question occur at the same time and a part of the striae of the figure must then correspond to the third harmonics.

In short, this fact shows us a remarkable and important thing that the characteristics of the present discharge figure depend only on the system in the discharge vessel and are quite independent of the other members of the circuit a certain electric oscillation due to which however must possibly excite to exhibit the R figure.

VI. Effect of Different Sizes of Electrode on the Dielectric Plate.

For generating the characteristic radial discharge figure, the electrode touching the upper surface of the dielectric needs not to be of a needle point but may be of another shape such as a circular disc.

Experiments are made by applying a circular disc of brass of various diameters in place of the needle point on the dielectric plate, and their results are given in the following Table XVII and some of them in Fig. 15.

TABLE XVII.

No.	Dielectrics D	Dielectrics L	Electric connection	Electroscopic deflection	Air pressure	S	C	Dia. of electrode	N I	N II	N III
	cm.	cm.			cm.	cm.	cm.	cm.			
1	Glass 10.0	0.163	A (I)					0	(25)	(50)	
					5.6	.044		1.0		52	
					4.3	.020		,,	26		
					6.0	.033		4.0		53	
2	,, 10.0	.173	,,					0	(23.5)	(47)	
					7.5	.040		0		48	
					5.5	.024		,,	23		
					6.1	.036		1.0		48	
					5.4	.022		,,	24		
					7.5	.033		4.0		49	
					8.4	.026		,,		48	
3	,, 10.0	.33	A (I)+C (III) (no earthing)					0	(18)	(36)	
					3.4	.027	.25	1.0	18.5		
1°	,,	.160	,, A (I)		3.5	.020	,,	2.0		47	
					3.3	.036	,,	,,		49	
4	,, 10.0	1.50	A (I) (brass pl. earthed)					0	(8)	(16)	(24)
				14.3	3.7	.020		1.0	9		
				8.0	2.3	.024		,,		16.5	
			,, (no earth.)	8.5	3.6	.057		2.0		16	
				10.0	3.8	.036		,,		16	
			(earthed.)	14.0	5.4	.038		4.0			23
			(no earthing)	8.0	3.2	.035		,,			24
5	,,	,,	A (III)+C (II) (no earthing)	10.0	2.5	.039	.17	1.0		17	
6	,,	,,	A (I) (no earthing)	10.0	4.0	.054	Cylinder D=2.0 L=5.0			16	
				4.0	2.4	.062				17	
7	Bakelite 10.0	.315	A (I)					0	(14.5)	(29)	
					4.3	.024		1.0	14		

TABLE XVII (continued).

No.	Dielectric D	Dielectric L	Electric connection	Electro-scopic deflec-tion	Air pres-sure	S	C	Dia. of elect-rode	N I	N II	N III
					cm.	cm.	cm.	cm.			
8	Bakelite		A (I)					0	(21.5)	(43)	
	cm. 15.0	cm. .315	A (I) + C(III)	8.0	3.9	.044	.5	1.0		44	
				8.3	3.1	.029	.23		25		
				10.0	3.0	.018	.18	2.0	22		
				5.5	2.5	.034	.17	,,		44	
				3.5	2.0	.012	.17	4.0		42	
9	Ebonite 3.0	.344	A (I)		5.6	.034		0	(3.2)	(6.3)	(9.5)
								,,			9
					5.3	.030		1.0			9

Discharge vessel: V I).
Electroscopic deflection: One division corr. to about 200 eff. volts.
D, L, S, C: Same as those described in the preceding Tables.
Temperature: 20 to 23°C.
0 in dia. means here the needle point electrode.
The values in the brackets are derived from the curves in the preceding Figs.

The R figure generated by the disc electrode are in varying degrees less fine than those by the needle electrode. Generation of stable R figures by a disc electrode more than 4 cm. in diameter is very difficult in the apparatus we are using.

The number of striae of the R figure by a disc electrode is approximately the same as that by the needle point. But there is a tendency, though negligibly small, that the number of striae increases with the area of the disc electrode.

Next, we have made some experiments on the R figure using two needle electrodes on the dielectric plate. The electric connection is

the first needle—a series spark gap—the secondary of the transformer—the second needle.

The dielectric plate is made, for convenience' sake, to a form having sides composed of a pair of semi-circles and a pair of straight lines, and the needle points of the electrodes above mentioned touch just on each of the centres of those semi-circles. The brass plate under the dielectric is left free or earthed. A few photographs of the R figure thus generated are shown in Fig. 15 (7–12). In cases where the brass plate is left free, R figures appear both around the two needle points, the number of striae of the figure around the second needle being very often just a half of that around the first one. In order that the system around the second needle should be excited (to a resonance at most) by the electric oscillation due to the system around the first one, the potential of the brass plate must be oscillatory in a certain degree, because the members in the electric circuit are distributed asymmetrically with respect to the brass plate. If the brass plate is earthed, the R figure appears only around the first needle which is directly connected to the spark gap; for, the second needle is quite excluded from the oscillation circuit by the earthing point, i.e., there is no spark gap in the circuit composed of the earth, the dielectric, the second needle and the secondary of the transformer. Therefore, if another spark gap is added between the second needle and the secondary of the transformer, the brass plate being earthed, the whole circuit then is separated by the earthed brass into two similar circuits which can generate R figures but are quite independent of each other.

Lastly, something should be said about the effects of the different sizes of the discharge vessel. We have made some experiments with vessels of different sizes shown below.

TABLE XVIII.

Vessel	Glass (hollow, circular cylinder) Dia.	Height	Brass plate
V (I)	21.0 cm.	22.5 cm.	$25.0 \times 30.0 \times 0.64$ cm.^{3}
V (II)	15.0	17.0	$\pi\left(\frac{19.0}{2}\right)^2 \times 0.30$,,
V (III)	,,	,,	$\pi\left(\frac{19.0}{2}\right)^2 \times 1.05$,,
V (IV)	20.0	28.0	$\pi\left(\frac{26.0}{2}\right)^2 \times 0.45$,,

In the sphere of our experiment there is no appreciable effect on the features nor on the number of striae of the radial discharge figure.

VII. Radial Discharge Figure on Plates of Various Dielectric Substance.

Observations are made with various dielectric substances besides glass plate, such as bakelite, ebonite, sealing wax, rubber, celluloid, cork, etc. We have been able to generate the characteristic radial discharge figures for all of those substances and all their sizes that we have employed. All of them have been hard enough not to be influenced by the electric discharges on their surfaces, but paraffin has been the only exception. When the source of the high electromotive force is the transformer previously mentioned, the part of the paraffin plate near the needle point electrode is melted by the discharge of a few minutes.

The results of observations are given in the following Tables and Figures and some photographs of the R figure obtained are shown also in Figs. 18, 19, 20 and 21.

i. Radial Discharge Figure on Plate of Bakelite.

TABLE XIX.

Variation of Number of Striae of the R figure on Circular Plate with Diameter, its Thickness being kept the same.

No.	Diameter of bakelite plate	Air pressure	Width of series gap	Number of striae I	II	III
1	15.0 cm.	3.4 cm. 3.7	0.038 cm. .088	22 (23)	 44	
2	14.0	3.5 3.1	.027 .066	20	 41	
3	13.0	4.3 3.1	.056 .028	 18	35	
4	12.0	3.3 5.0	.073 .034	 17	34	
5	11.0	4.0 3.7	.021 .035	15.5	(30) 30	

TABLE XIX (continued).

No.	Diameter of bakelite plate	Air pressure	Width of series gap	Number of striae I	II	III
6	10.0 cm.	3.8 cm.	0.018 cm.	(14.5)	29	
		4.2	.024	14.5	29	
		8.8	.038	14		
		6.3	.039		30	
7	9.0	3.5	.020	12.5		
		4.4	.039	(13)	25	
		5.0	.020	11.5		
8	8.0	4.3	.037		22	
		3.7	.024	11		
9	7.0	3.6	.024	12		
		4.5	.032		18.5	30
10	6.0	6.4	.070			24
		4.3	.021		16	
11	5.0	4.0	.076			21
		7.5	.026		13	
12	4.0	7.2	.016		11	
13	3.0	8.0	.019		8	
		6.8	.052			13

Thicknesses of bakelite plates: 0.315 cm.
Discharge vessel: V (I)
Electric connection: Type (I) in Fig. 1.
Temperature: 20 to 23° C.

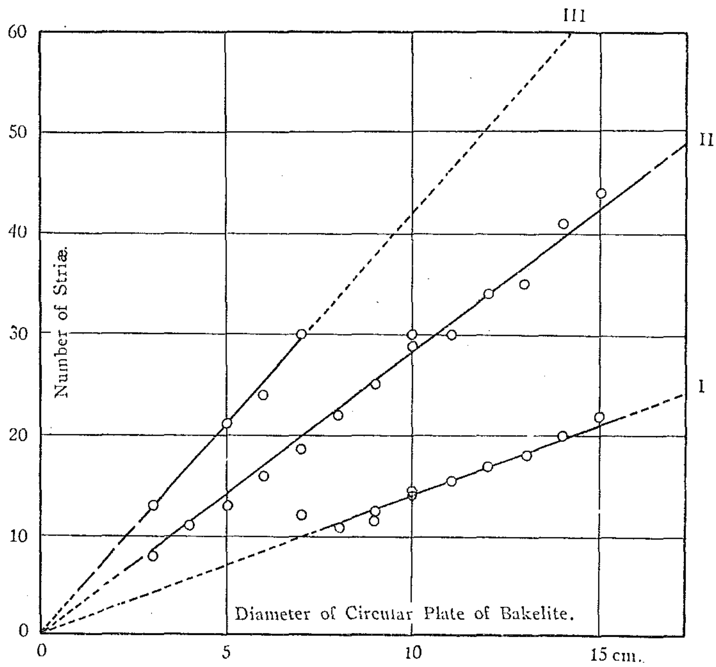


Fig. 16.

ii. Radial Discharge Figure on Ebonite.

TABLE XX.

Variation of Number of Striae of the R figure on Circular Ebonite Plate with Diameter, its Thickness being kept the same.

No.	Diameter of ebonite plate	Air pressure	Width of series gap	Electro-scopic deflection	Distance betw. plates o condenser	Number of striae I	II	III
1	15.0 cm.	4.3 cm.	0.098 cm.	10.5	1.0 cm.		38	
		3.5	.031	11.5	,,	19		
2	14.0	4.0	.044	12.0	,,		31	
		4.1	.080	11.0	,,		35	
3	13.0	4.0	.078	9.7	,,		32	
4	12.0	3.6	.038	8.0	,,		28	
		,,	.021	9.7	,,	17		
5	11.0	3.9	.021	9.0	,,		26	
6	10.0	7.1	.038			13		
		3.5	.042				22	
		5.9	.028)°				22	
		5.8	.050		2.0			32
		5.4	.025		,,		23	
7	9.0	2.9	.023	5.8	1.0		21	
		3.8	.050	6.2	,,			32
8	8.0	4.5	.032	7.5	,,		20	
		6.5	.044				19	
		4.3	.105					28
9	7.0	5.6	.022	8.5	,,		17	
		5.0	.076	7.5	,,			24
		6.5	.016				16	
		4.3	.067					25
10	6.0	6.5	.016	9.0	,,		12.5	
		5.2	.018	8.0	,,			19
		5.5	.019				14	
		5.0	.016			7.5		
11	5.0	5.9	.015	8.3	,,		12	
		4.4	.026	5.5	,,			20
12	4.0	6.0	.015	8.5	,,			13
		6.1	.013	9.0	,,		9	
13	3.0	7.5	.020	8.2	,,		7	
		4.0	.010	4.5	,,			10

Thickness of ebonite plate: 0.305 cm.
Discharge vessel: V (I)
Electric connection: A (I) and C (III)
Electroscopic deflection: One division corresponds to a potential difference of about 200 eff. volts.
—)°: The R figure is generated by a spark gap having spherical ends both of 1 cm. diameter.
Condenser: A condenser of two circular brass plates both 25 cm. in diameter and an ordinary window glass 0.17 cm. in thickness being inserted between the plates.
Temperature: 19 to 23° C.

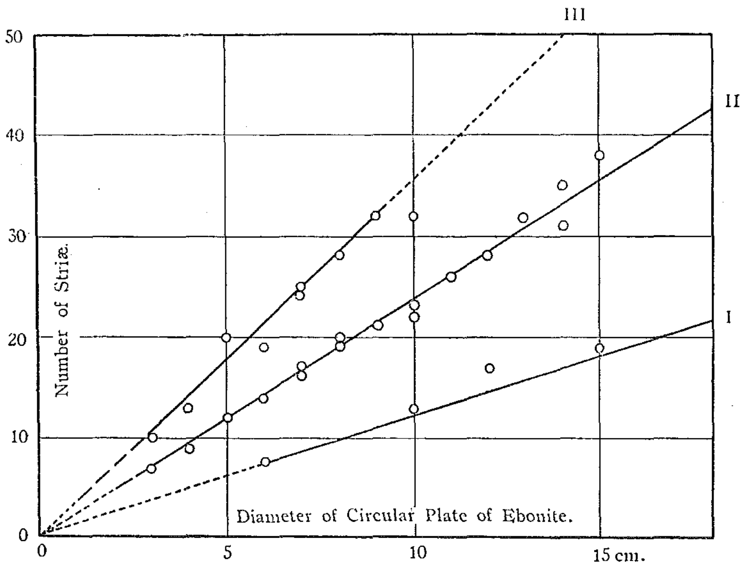


Fig. 17.

iii. Radial Discharge Figure on Circular Plate of Sealing Wax.

TABLE XXI.

No.	Wax plate. Diameter	Wax plate. Thickness	Air pressure	Width of spark gap	Number of striae I	Number of striae II	Number of striae III
1	10.0 cm.	0.30 cm.	3.6 cm.	0.023 cm.		35	
2	,,	.27	4.2 4.4	.030 .020	17 19		
3	8.95	.33	4.5	.041		29	
4	,,	.82	4.0	.017		13	
5	7.2	.315	4.3	.020	12		
6	7.05	.33	4.0	.020		22	
7	6.0	1.555	4.6	.068			13
8	,,	,,	4.4	.016		8	
9	,,	.90	3.8	.021		11	
10	5.05	.345	5.3	.039			20
11	,,	.37	,,	.016	8		

Discharge vessel: V (I).
Electric connection: Type (I) in Fig. 1.
Temperature: 20 to 23°C.

iv. Radial Discharge Figure on Rubber.

TABLE. XXII.

No.	Rubber plate D	Rubber plate L	Electric connection	Air pressure	S	C	Number of striae I	II	III
1	5.1 cm.	0.31 cm.	A (I)	4.3 cm.	0.012 cm.			13.5	
2	5.9	,,	,,	4.2	.015			15	
3	7.0	,,	A (I) + C (III)	4.0	.011	0.17 cm.		18	
				5.8	.020	,,		18	
4	,,	.58	,,	5.2	.041	1.0			22
				4.4	.019	,,		14	
5	,,	1.30	,,	4.5	.027	.5		10	
				4.2	.043	.17			13
6	,,	1.90	,,	5.0	.027	.30		7.5	
				5.1	.043	,,			13
7	5.0	.60	,,	6.3	.018	.18		9.5	
				5.2	.019	.17		10	

D, L: Diameter and Thickness of the circular plate of rubber.
S: Width of the spark gap.
C: Distance between two brass plates of the condenser mentioned already.
Electric connection: A (I) without earthing for No. 1, 2.
A (I)+C (III) without earthing for all others.
Discharge vessel: V (I).
Temperature: 20 to 23°C.

We have been able to generate fine radial discharge figure on rubber having small circular surface and great thickness (rubber plugs are used) like the cases with glass cylinders.

v. Radial Discharge Figure on Celluloid.

TABLE XXIII.

No.	Circular plate of celluloid D	Circular plate of celluloid L	Air pressure	S	Number of striae I	II
1	7.0 cm.	0.20 cm.	4.1 cm.	0.018 cm.		30
			4.0	.005	15	
2	8.1	,,	5.6	.034		35
			,,	.010	18	
3	,,	.40	4.0	.028		23
			4.4	.030		24

Dielectric: Transparent and yellow coloured plate of celluloid (circular ones being prepared from a set square).
Electric connection: Type A (I) without earthing.
Discharge vessel: V (I)
Temperature: 20 to 22°C.

vi. Radial Discharge Figure on Paper.

TABLE XXIV.

No.	Circular paper		Air pressure	S	Number of striae	
	D	L			I	II
1	10.0 cm.	0.127 cm.	4.8 cm. 5.5	0.034 cm. .014	 19	36
2	"	"	5.3 3.6	.043 .012	 22	38

Dielectric: A paper of moderate hardness and of a mat surface.
Electric connection: A (I) without earthing.
Discharge vessel: V (I).
Temperature: 21°C.

For observations given in No. 2 of the above Table, tin foil is pasted all over the lower surface of the paper lest some air space should remain between the paper and the brass plate. The number of striae of the R figure for this case is larger than that without the tin foil.

vii. The characteristic R figure has been generated for every case that we have tried with dielectric substances, besides those above mentioned, namely, cork, paraffin, mica, etc. The figure generated on a cork plug is especially beautiful. (Fig.20).

viii. Radial Discharge Figure on Wood.

We have made experiments about the peculiar discharge figure hitherto with homogeneous and isotropic dielectrics such as glass, bakelite, etc. We have now taken some woods as an example of an axial (inhomogeneous) dielectric. The features of the radial discharge figure on the wooden plate are somewhat different. The striae radiated from the electrode curve in a regular manner even with a circular plate. It is an interesting fact that the porosity of the wood has almost no effect on the features of the radial discharge figure. A few examples of the observations with wooden plates are given in the following Table and Fig. 21.

TABLE XXV.

No.	Circular plate of wood	D	L	Air pressure	S	C	Number of striae I	II
1	*Kiri*, very soft, porous. (Fig. 21)	cm. 10.0	cm. 0.46	cm. 4.0 5.4 ,,	cm. 0.003 .008 .046	cm. 0.3 .18 ,,	14 14	27
2	*Sen*, moderately hard, porous, straight grains on the surface.	,,	.57	4.9 5.3	.008 .043	.4 .8	13	25
3	*Katura*, small porous.	9.0	.36	6.0 5.6	.021 .084		14	27
4	*Nara*, large porous, hard, straight grains on the surface.	9.0	.40	8.0 4.3	.054 .027		10	19

Dielectric: Dry wood of the form of circular plate.
Discharge vessel: V (I).
Electric connection: A (I) and C (III) without earthing for No. 1,2;
A (I) for No. 3, 4.
Temperature: 20 to 22°C.

From the results of the above observations with various dielectric substances, we can determine the following relations.

a. With the same apparatus and management, we can generate the characteristic radial discharge figure on the surface of any dielectric substance (having any form and size).

b. For any dielectric substance, the number of striae of the R figure generated on it varies regularly with its size. If the substance under consideration be homogeneous and isotropic as any one but wood given in the preceding, the variation of the number of striae of the R figure on the substance with its size is just like that with glass, provided that the form of the substance to be tested be of the same kind as that of the glass, say of circular plate (or circular cylindrical).

c. The numbers of striae of the figures on different dielectric substances having however the same size are different from one another. The parameter showing the differences in the numbers of striae for different substances depends entirely on the nature of the substance itself, if the gas in the discharge vessel is given. In the sphere of our present investigations, the dielectric constant is a single one which has a close relation to this parameter. The quantitative discussions about these circumstances will be given later.

d. The heating effect on the dielectric by the discharge during the appearance of the characteristic figure is roughly as follows :— Paraffin is melted near the needle point in one or two minutes by the discharge. Next, the ebonite is somewhat influenced by a long discharge also near the needle point which even plunges into the ebonite though slightly. This melting however has no effect on the striae of the discharge figure at least at air pressures suitable for generating the characteristic R figures. But at air pressures of more than about 10 cm. of mercury, the surface of the edonite is much stained by the striae or streams of the discharge in a few minutes. All the other dielectrics are unaffected by the discharge.

e. For an inhomogeneous dielectric substance, the features of the R figure are somewhat different from those for a homogeneous one. In the case of an axial substance such as wood, the striae radiated from the electrode (commonly a needle point) curve more or less along the direction just at right angles to the dielectric axis itself. Consequently, the striae of the figure are most numerous along the direction at right angles to the dielectric axis and rarest along that parallel to the axis. It must be due chiefly to the fact that the dielectric constants in these two directions are quite different from one another. The striae are most numerous along the direction at right angles to that of the porosity, which coincides with a wooden axis in view of dielectric constant.

VIII. Effect of Electric Current on the Radial Discharge Figure.

If we increase the electric current through the discharge vessel by decreasing the resistance in the primary circuit, the striae of the radial discharge figure become brighter, but the number of the striae is not changed by different intensities of the current.

There is a limit, however, to the intensity of the electric current for keeping the stable and fine R figure on a given dielectric plate. If the intensity of the current exceeds this limit, then unsteady and crackling discharges may take place, and the characteristic radial discharge figure will be more or less faint (the degree of this effect is due to conditions such as the electric connection, the size of the dielectric, etc.). However, the characteristic figure, though the brightness of the striae is decreased by the superposed discharge streams, is quite steady as before, and the number of striae also remains the same. This fact suggests that the present figure is quite another class of discharge figure than ordinary discharges at low air pressure and that the features of the figure is perfectly characteristic to the given system in the discharge vessel.

Next, in order to determine if the cycle or the wave form of the applied alternating electromotive force effects the R figure, we have made experiments using some different sources for producing a high and alternating electromotive force.

Many results of the observations using the transformer as a high tension producer are given in the preceding. We have accordingly made like observations by using an induction coil which has a spark length of 30 cm. and is powerful enough to produce the radial discharge figure. (Table XXVI, Fig. 22).

Table XXVI.

R Figure using the Induction Coil.

No.	Dielectric D L	Electric connection	E.D.	M	S	C	Cycles of curr.	N I	N II	N III
1	cm. cm. Glass 10.0 0.165	A (I) +C (III)	8.5	cm. 4.8	cm. 0.024	cm. 0.18	40		48	
			8.0	5.4	.004	1.5	,,	24		
2	Glass 10.0 1.50	A (III)	11.7	4.5	.095		,,		17	
			15.0	4.5	.200		,,			25
3	,,	A (I)+C (III) (no earthing)	7.3	4.1	.042	.17	20		16	
		A (II)+C (III) (needle earthed)	14.0	4.2	.024	.18	40		16.5	
4	Bakelite 10.0 .315	A (II)+C (III) (no earthing)	7.5	4.4	.015	.18	40	14	29	
		A (I)+C (III) (no earthing)	7.0	4.5	.022	,,	,,	14	29	
			4.5	3.7	.020	,,	20	15	29	
5	,,	A (III)+C (III) (no earthing)	5.2	3.2	.066	1.5	20		29	

Dielectrics: Circular plates.
Discharge vessel: V (I).
E.D.: Electroscopic deflection of which one division corr. to about 200 eff. volts.
M: Air pressure in cm. of mercury.
D, L, S, C, N: same as those in the preceding Tables.

We see from the results that

i. the R figure obtained in this case has the same features as that obtained when the transformer is used. In a few cases (with a glass plate and for electric connections where a spark gap is connected in series), the R figure generated is less beautiful.

ii. the number of striae of the R figure is the same for both cases whether using the transformer or the induction coil, if the system in the discharge vessel is given.

iii. the number of striae and the features of the R figure are not affected by the cycles or the wave form of the applied electromotive force (here the electric oscillation of very high frequency which may occur in the circuit during the discharge is not taken in consideration).

IX. Effect of Different Forms of Dielectric on the R Figure.

As one of the means for discriminating the present discharge figure from electric discharges which will occur commonly in low pressures of gas, we have repeated similar observations with homogeneous dielectrics of various forms, and obtained some interesting results as following :—

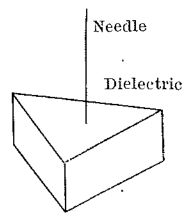
1. A circular plate : With dielectrics of this form we have made all the quantitative measurements described in this essay ; a chief characteristic feature in this case is that the striae of the R figure radiate with equal angles to each other from the centre.

2. A square plate : For a thin square plate, the number and the distribution of the striae of the R figure generated on its surface are almost the same as those of a circular plate having the same area and the same thickness. It is noteworthy that the bright striae radiate both diagonally and perpendicularly to the sides of the square. If we increase the electric current over its proper amount for the R figure, unsteady crackling discharge streams will occur along the shortest distances between the needle point and the boundary of the dielectric plate, but the R figure above mentioned is not at all affected by these excessive discharge streams and continues to have the same features as before. Fig. 23 (1) is an example of the figure produced on a square glass plate of 10.0 cm. sides and 0.167 cm. thickness.

3. A triangular plate : The features of the R figure generated on a thin triangular plate are almost like the preceding, and the bright striae in the directions towards the corners vanish on their way (but are never bent) with a moderate electric current

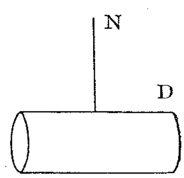
which should however be more than sufficient for striae on the greater part of the plate. The (circular) area on which the bright striae appear depends much on the width of the spark gap in the circuit, and the circular boundary of the R figure thus partly generated is quite distinct. Fig. 23 (2) will show these characters.

An R figure having peculiar and indeed curious aspects is obtained with a thick triangular plate. Fig. 23. (4) *a*, *b* are the R figures generated on triangular surface of an optical prism of 3.07 cm. thickness and 5.0 cm. each of the three sides. We can make appear, by regulating the width of the spark gap, one or two bright striae just on each corner of the triangle and none on the other parts. For widths of the gap larger than that suited for these figures, some more striae will appear also on the sides of the triangle. It may be of little use to mention that unsteady crackling discharge streams would occur, besides the above R figure, along the shortest distances between the needle point and the edge of the glass, if the electric current be increased over an amount suitable to realize the figure.



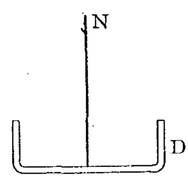
4. A rectangular plate: The number of striae of the R figure is rather more numerous in the direction parallel to the longer side than perpendicular to it. Fig. 23 (3), *a*, *b*, *c*, are the R figures for different widths of the series spark gap with a rectangular glass of 10.0 cm. and 5.0 cm. sides and 0.16 cm. thickness. Fig. 23 (5) is another with a thicker plate of quartz.

5. A cylinder, the axis of which is set horizontally on the brass plate: The needle in this case touches perpendicularly in the middle of the cylindrical surface. The result is so curious that the number of striae of the figure generated is the most numerous in the axial direction and the rarest in the direction perpendicular to the axis. (Fig. 23



(8), *a*, *b*)

6. A wedge: The number of striae of the R figure is the most numerous in the direction of the smallest thickness and rarest in that of the largest, provided that the dielectric substance is homogenous and isotropic. Fig. 23 (6) is the R figure produced on the circular surface of a wedge shaped piece of bakelite, and Fig. 23 (7) is the same on the square surface of a wedged piece of wood, the gradient of thickness being made at right angles to the axis of the piece.



7. A disc having a vertical edge: The R figure appears correspondingly to the size of the dielectric, but the figure in this case has very poor features. The figure is much disturbed by the vertical edge and there appears no striae near it. This fact shows that the bright striae of the R figure are certain discharge flowings and not statical assemblages of some luminous particles. (Fig. 23 (11)).

8. An air space between the dielectric and the brass plate: We have made observations with a circular glass plate keeping a uniform air space between it and the brass below. The R figure generated on this glass plate is very unstable and poor in appearance. The number of striae of the figure, on the other hand, is much smaller even comparing it to that obtained when placing directly on the brass plate a circular glass having the same diameter and a thickness equal to the sum of both the glass and air space in the present case. We see from this fact that the R figure in this case depends much more on the thickness of the air space between the glass and the brass plates rather than on the glass plate itself. Some deeper considerations on this fact will be given later in the chapter of general discussions about the R figure. (Fig. 23 (9), *a*, *b*).

Fig. 23 (10) is the R figure generated on a thin glass (0.16 cm. in thickness) of which one edge is elevated only one fourth of the thickness of the glass plate from the brass plate while another touches the brass plate in a point. The features and the number of striae of the figure generated on the glass is affected very much by this thin air wedge, and the striae of the figure are very concentrated in the direction of the touching point and rarefied contrariwise in the opposite direction.

Thus we see that the air film between the glass plate and the brass plate (or between glasses if a number of thin plates be piled together) causes the greater part of the errors in both the number and distribution of striae of the figure generated on the dielectric plate. Therefore it is recommended, for more accurate measurements, to use a single dielectric plate and to have its base (the lower surface touching the brass plate) pasted to a tin foil.[1]

9. Two plates of different substances combined together: We have made experiments with combined circular plates of glass and bakelite and of glass and ebonite by setting them both surfaces upwards alternately. The results are given in the following Table and some of them are shown also in Fig. 23. (12), *a*, *b* and (13) *a*, *b*.

---

1) If the above relation holds true, the number of striae measured in the preceding must, owing to some thin air space which should remain accidentally between the dielectric and brass plates, be less than that of a R figure which shall be generated on the same dielectric having however no air space at all. But the chance of the error may be such that its probability is the same for each of the different surface areas of the dielectrics, if all their thicknesses are equal. Further this relation must hold, in view of the probability, in any cases of different sizes of the dielectric plate, provided that each of the dielectric sheets (which compose the dielectric under consideration) should have the same thickness (or more generally, that the thickness of the dielectric should always be proportional to the number of the sheets composing it). Thus the relations between the number of striae of the R figure and the size of the dielectric which are shown in the preceding Tables and Figures hold true, despite that the number of striae itself should be somewhat less than its true value.

TABLE XXVII.

No.	Dielectric	Diameter	Thickness	Air pressure	Width of spark gap	Number of striae I	Number of striae II
		cm.	cm.				
1	glass	10.0	0.17	4.2 cm.	0.021 cm.	13	
	+		+				
	bakelite	,,	.315	5.2	.042		25
2	bakelite	,,	.315	4.3	.032		25
	+		+				
	glass	,,	.17	3.9	.008	13	
3	,,	,,	,,	3.9	.040		26
				5.2	.013	14	
4	glass	,,	.17	3.6	.042		22
	+		+	4.2	.041		21
	ebonite	,,	.305	2.9	.027		21
5	ebonite	,,	.305	4.2	.008	13	
	+		+				
	glass	,,	.17	3.6	.024		22

Discharge vessel: V (I).
Dielectric: Circular plate of glass and bakelite or glass and ebonite combined together. D=10.0 cm.

$$L=\begin{cases}0.17 \ldots\text{glass.}\\ 0.315\ldots\text{bakelite.}\\ 0.305\ldots\text{ebonite.}\end{cases}$$

Electric connection: Type A (I) without earthing.
Temperature: 20 to 23°C.

We see from the above results that the number of striae of the R figure is approximately the same for both cases of different upper surfaces. Therefore the number of striae of the figure is independent of the surface of the dielectric, provided that the size of each sheet (composing the dielectric plate) should remain the same.

In short, the results obtained by the above observations are very particular and characteristic, and in fact some of them are apparently quite contrary to those expected before the observations.

The chief and most important facts shown by the observations are that

a. the R figure is quite a different kind of electric discharge from ordinary electric discharges, which are unsteady, with crackling, streaming or sparking.

b. the characteristics of the R figure, therefore, do not necessarily have relation to the same factors (members in the electric circuit, say, a resistance, a capacity or an inductance) to which the ordinary discharges have close relations.

c. the R figure seems apparently to attach or to belong to the dielectric itself; in other words, in respect to its generation the R figure seems to be much closer to the dielectric than to the other parts of the electric circuit.

Part II. Discussions about the Results of Experiments on the Radial Electric Discharge Figure.

I. Proposition of a Peculiar Electric Oscillation and Application of a Theory of Resonance to the Radial Discharge Figure.

We may imagine that the radial discharge figure described in the preceding is a result due to certain electric oscillations and their resonance in the circuit, for the following reasons :—

i. Notwithstanding that the electric current in the circuit is alternating, the radial discharge figure generated by it is quite stable, and no such figures appear with a direct current. This shows that some changes of the intensity of the electromotive force are necessary for obtaining the R figure.

ii. When the most stable and finest R figure is generated, there is such an inertia that small variations of the width of the spark gap from its proper value has no effect on the stability of the figure. This fact suggests to us the existence of a certain resonance of electric oscillations in the circuit.

iii. In most cases in the observations, we can obtain with the same dielectric plate, two (or sometimes more than two) kinds of R figure in which the number of striae of one is just twice the other, and these two can be generated even by a mere regulation of the width of a spark gap. We may most possibly suppose that one of the above two figures corresponds to the second harmonics of a certain electric oscillation which is proper to another.

iv. The number of luminous striae (or of dark canals) which are the principal characteristic feature of the R figure remains the same even if we vary

  a. the cycles or the wave form of the applied electromotive force,
  b. the intensity of the electric current in the circuit,
  c. the air pressure within its allowable range for producing the R figure,
  d. the width of the spark gap,
  e. kinds of electric connection of the secondary circuit in which the discharge system in question exists,
  f. the resistance, the capacity or the inductance in the secondary circuit,
  g. the size of the discharge vessel of glass or the brass plate on which the dielectric is set,
  h. the needle point electrode (on the dielectric) to a disc electrode,

  provided that the dielectric and its size are given. These facts show that the R figure is a phenomenon depending only on the dielectric, its size and perhaps the nature of the gas in the discharge vessel and quite independent of the other parts of the electric circuit, (at least in respect to the number of striae which however are the principal characteristic of the R figure).

v. If the dielectric plate and the air pressure are given, the width of the spark gap for obtaining the most stable and beautiful R figure can be determined. This fact suggests to us the existence of a certain electric oscillation in the secondary circuit which greatly influences the discharge system to make the R figure appear. And we may well consider that the frequency of this electric oscillation due to the circuit can be regulated by varying the width of the spark gap, and that the same oscillation, when conditions are the most favourable, makes a resonance with another peculiar oscillation which is due merely to the system in the discharge vessel. It may be very reasonable from the circumstances above described to suppose the existence of a certain proper electric oscillation of the system in the discharge vessel.

vi. The R figure is quite different from ordinary discharge flows in features, in distribution of luminous striae or streams, in stabilities, in relations between it and members in the electric circuit, ete. We see these peculiarities apparently in the photographs shown (especially in those with dielectrics of various forms). This fact gives also a reason to the supposition of the peculiar electric oscillation, proposed above, to which the peculiar discharge figure is due.

Thus we can propose the following considerations about the R figure, a peculiar class of electric discharge figure :—

A high and instantaneous electromotive force caused by any means produces in the circuit (the secondary when the source is a transformer) a certain electric oscillation of very high frequency, if there exists, in the same circuit, a spark gap or anything which works like a spark gap. This also is a damped oscillation, and when the source of the high electromotive force is a transformer of 60 cycles, a group of the damped electric oscillations of high frequency occurs in the circuit just 60 times in a second. The frequency of this oscillation depends on the capacity, the inductance and the resistance in the circuit.

Next, there is another damped electric oscillation besides the above mentioned. This occurs in the discharge vessel in question, and the frequency of oscillation depends merely on the dielectric, its size and the nature of the gas in the discharge vessel and is quite independent of the other parts of the electric circuit. The R figure is nothing but an effect due to this proper oscillation or often to its higher harmonics, and the number of striae of the R figure corresponding to the latter is a simple multiple of that corresponding to the former. Considering the fact that different varieties of the R figure (which correspond to the oscillations of quite different frequencies) can be generated merely by changing the width of the spark gap, the frequency of this peculiar oscillation may be still larger than that of the electric oscillation which is due to the electric circuit. It may not be useless to say that this particular oscillation is excited and the corresponding R figure appears every time when a suited electric oscillation due to the circuit occurs (60 times per second when using the above denoted transformer) and that this fact can easily be noticed by observing the figure or the sparks at the gap through a rotating mirror.

In conclusion, when the electric oscillation due to the circuit is sufficiently powerful and its frequency is not very greatly different from that of the proper oscillation or its higher harmonics, each being due to the system in the discharge vessel, the former oscillation forces and excites the latter and the R figure corresponding to the latter oscillation appears consequently. In such a favourable case when these two electric oscillations just resonate with each other, the most stable and finest R figure appears.

II. On the Number of Striae of the R Figure.

It may be seen from the results of experiments already described that the number of striae of the R figure depends only on the size and the substance of the dielectric and is quite independent of the other members and their magnitudes in the electric circuit, provided that the gas in the discharge vessel is given.

On the other hand, the results of the measurements with dielectric plates of various sizes show us that

i. variable factors which have close relation to the number of striae of the R figure are the thickness, the area of the upper surface and the nature (dielectric constant) of the dielectric plate, if the gas in the discharge vessel is given,

ii. these variables relate to the number of striae as if they are just the members of a parallel plate condenser having the same dielectric substance between two discs of conductor of the same area and the same distance, and the square root of this apparent capacity is just proportional to the number of striae,

iii. the number of striae is directly proportional to the harmonic number of the oscillation due to the system in the discharge vessel,

iv. the number of striae is also a function of the nature of the gas in the discharge vessel.

Thus we have

$$N \propto k.\ G. \sqrt{C}, \tag{1}$$

where k, the harmonic number equals 1, 2,.... ; G, the function due to the gas in the discharge vessel, and C the apparent capacity due to the size and the constant of the dielectrics. And

$$C = \frac{KD}{4\pi L}, \tag{2}$$

in the case where the dielectric substance is a circular plate having D cm. diameter and L cm. thickness, and if K is the dielectric constant along the striae.

For convenience of comparison, the numbers of striae of the figures corresponding each to the dielectrics which are circular plates of the same size (say, 10.0 cm. in diameter and 1.00 cm. in thickness) can at once be deduced from the preceding observations represented by data and curves.

Thus we have obtained the following values, which are the numbers of striae of the figures corresponding each to the second harmonics of oscillations which are due to the given dielectric substances having each 10.0 cm. diameter and 1.00 cm. thickness.

For glass ....19.7±0.2
bakelite ....16.0± .3
ebonite ....13.2± .3

sealing wax	18.2± .5
rubber	14.2± .5
celluloid	19.2± .4
paper	13.2
wood (No. 1)	18.2

The squares of each of the above values are very likely to be proportional to the dielectric constants of the corresponding substances.

III. Summary and Conclusions.

The results of the present investigation are summarized in the following :

i. A new class of electric discharge figures at low pressure of gas is introduced.

ii. The apparatus, the electric connections and the method for generating the characteristic radial discharge figure are described.

iii. Characteristic features of this peculiar figure and some comparisons of the figure and the circular spark (which has been already introduced in our former work) are described.

iv. The features of the figure change regularly with the variation of the pressure of the gas in the discharge vessel, but the number of striae which are the principal features of the figure remains the same. There exists a proper range of pressure for generating the R figure on a given dielectric plate.

v. The variation of the width of the spark gap gives some regular changes in the features of the figure, but the number of striae remains the same so long as the stable figure appears. There is however a special case where two kinds (or sometimes more than two) of different R figures appear of which the number of striae in one is just twice the other (or the ratio of the numbers is very simple such as two to three or one to three). In these two cases the widths of the gap are quite different commonly. There exists a proper width of the spark gap for producing the most stable and finest figure in each case.

vi. The number of striae of the R figure varies regularly with different sizes of the dielectric in the discharge vessel.

vii. The number of striae varies with the substance of the dielectric and also with the gas in the discharge vessel. The result of observations using glass, bakelite, ebonite, sealing wax, rubber, cork, etc. with air are given, and some experiments using glass with hydrogen gas or oxygen gas have been made, though the latter are not described in this essay.

viii. If the dielecric (and the gas) in the discharge vessel be given, the number of striae of the figure generated on the dielectric remains the same by varying

a. the source of the high and alternating electromotive force, its cycle and its wave form, (we have experimented the circumstances by using a transformer or an induction coil.)

b. intensity of electric current in the discharge vessel,

c. the size of the discharge vessel,

d. the electric connections in the secondary circuit in which the discharge system exists, and the resistance, the capacity or the inductance in the same circuit,

e. the pressure of the gas in the discharge vessel or the width of the spark gap,

f. the needle point electrode (in the discharge vessel) to a disc electrode.

ix. Peculiarities of the present radial discharge figure are manifested very distinctly by the figures generated on various different forms of the dielectric. The R figure on the surface of wood, an unhomogeneous substance, shows us also some peculiarities.

x. Discussions are given about the results of experiment on the radial discharge figure, and a peculiar electric oscillation which is only due to the system in the discharge vessel and corresponding directly to the figure generated on the dielectric surface is proposed.

xi. A relational formula among the number of striae of the figure, the size, and the constant of the dielectric substance is introduced and compared with the experimental results.

In conclusion, we remark here about the future development in the researches on the present discharge figure, for there remain many untouched and only partly touched problems concerning it both theoretically and experimentally, namely

a. the mechanism, why and how the discharge flow is separated into striae which are stable and regularly distributed, (that is a fundamental problem of the phenomenon),

b. the effect of different gases in the discharge vessel,

c. the potential differences on both sides of the dielectrics in the discharge vessel and relations between them and the air pressure, the intensity of the electric current through the discharge vessel, the width of the spark gap, etc.,

d. the curvature of the flowing of the bright striae down from the edge of the dielectric, especially in the case of a thick dielectric,

e. the determinations of the frequencies of electric oscillations concerning the present discharge figure,

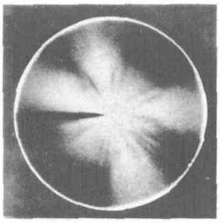
f. the luminous halo accompanying the figure and so on.

Some of them are now under investigation and their results will be published in the near future.

The Physical Institute of the Engineering
Faculty, Hokkaido Imperial University.

Fig. 2 Effect of different air pressures on the R figure on a thin circular glass plate.

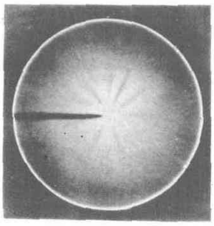
1



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

P=24.0 cm.
S=0.017 cm.

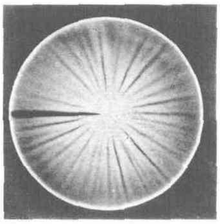
2



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

P=17.5 cm.
S=0.020 cm.

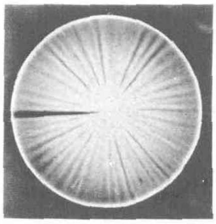
3



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

P=14.5 cm.
S=0.046 cm.

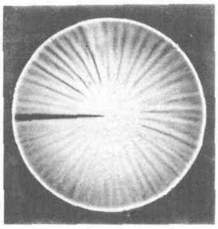
4



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

P=10.8 cm.
S=0.046 cm.

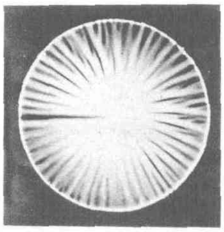
5



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

P=8.6 cm.
S=0.033 cm.

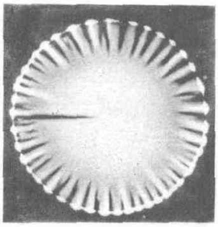
6



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

P=6.0 cm.
S=0.026 cm.

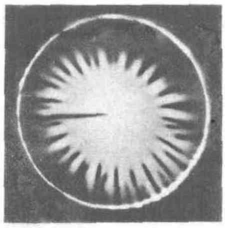
7



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

P=3.4 cm.
S=0.028 cm.

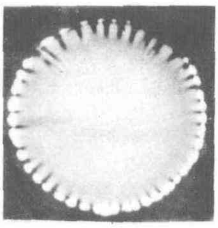
8



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

P=3.2 cm.
S=0.012 cm.

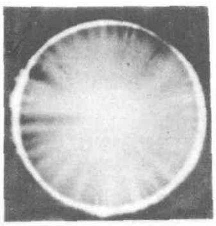
9



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

P=2.5 cm.
S=0.038 cm.

10



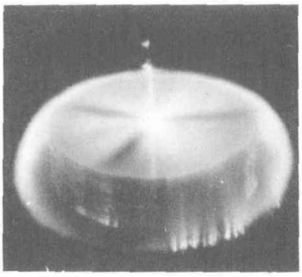
$\times \frac{1}{4}$

P=1.8 cm.
S=0.034 cm.

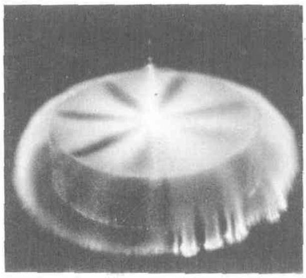
Fig. 3. The radial discharge figure at different stages of air pressure and width of the spark gap.

Dielectric: A circular plate of 11 cm. dia. & 2.5 cm. thickness consisting of 15 sheets of ordinary window glass.

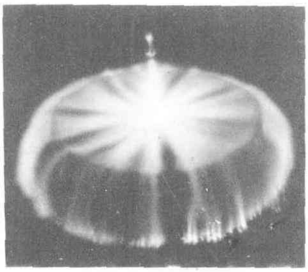
Electric connection: Type II in Fig. 1.

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

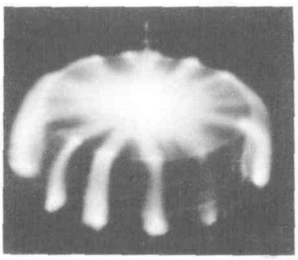
$P=9.5$ cm.
$S=0.015$ cm.

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

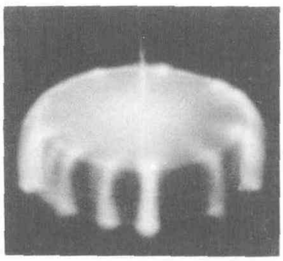
$P=5.4$ cm.
$S=0.024$ cm.

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

$P=4.3$ cm.
$S=0.036$ cm. (improper width)

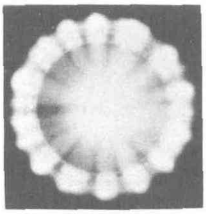
4  $\times \frac{1}{4}$

$P=2.5$ cm.
$S=0.048$ cm.

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

$P=1.5$ cm.
$S=0.048$ cm.

Fig. 5 A circular cylindrical glass: $D=5.0$ cm., $L=2.0$ cm.

1 

$\times \frac{1}{3}$

$S=0.088$ cm.

Resonanced

2 

$\times \frac{1}{3}$

$S=0.136$ cm.

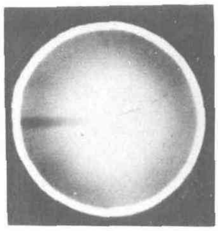
Unresonanced

Fig. 6. Effect of differeut widths of the spark gap on the R figure on a thin circular glass: $D=10.0$ cm., $L=0.170$ cm.

1 

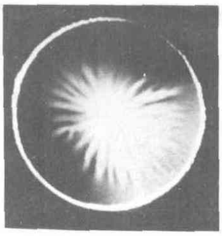
$\times \frac{1}{4}$

$S=0.000$ cm.

2 

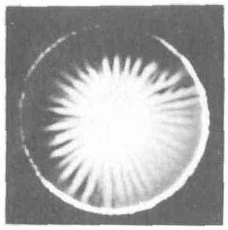
$\times \frac{1}{4}$

$S=0.001$ cm.

3 

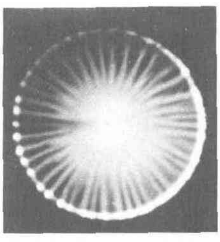
$\times \frac{1}{4}$

$S=0.009$ cm.

4 

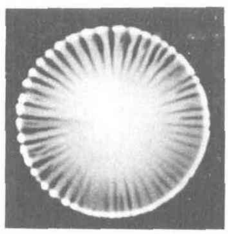
$\times \frac{1}{4}$

$S=0.028$ cm.

5 

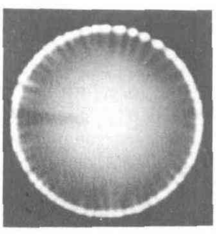
$\times \frac{1}{4}$

$S=0.036$ cm.

6 

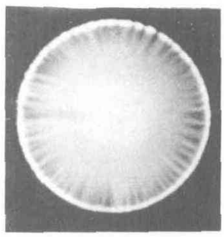
$\times \frac{1}{4}$

$S=0.052$ cm.

7 

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

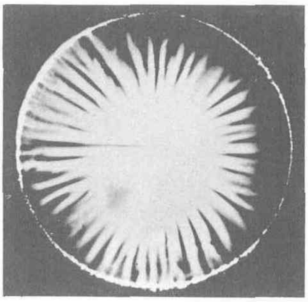
$S=0.150$ cm.

8 

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

$S=0.300$ cm.

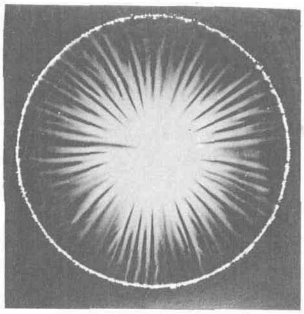
Fig. 11. Different kinds of the R figure on the same glass plate.



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

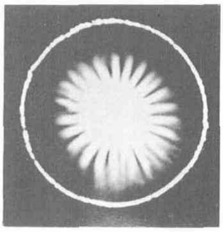
$S=0.024$ cm.
$P=3.2$ cm.

$D=15.0$ cm.
$L=0.177$ cm.



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

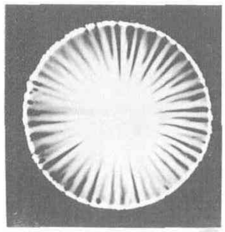
$S=0.081$ cm.
$P=5.3$ cm.



$\frac{1}{4}$

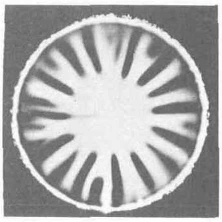
$S=0.014$ cm.
$P=3.7$ cm.

$D=10.0$ cm.
$L=0.173$ cm.



$\frac{1}{4}$

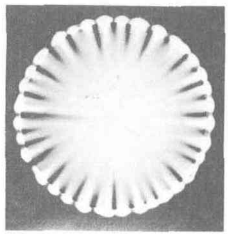
$S=0.030$ cm.
$P=5.5$ cm.



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

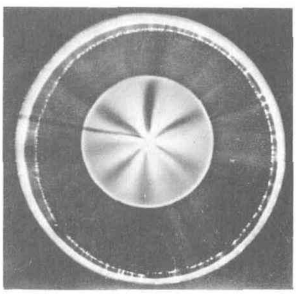
$S=0.019$ cm.
$P=2.8$ cm.

$D=10.0$ cm.
$L=0.496$ cm.



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

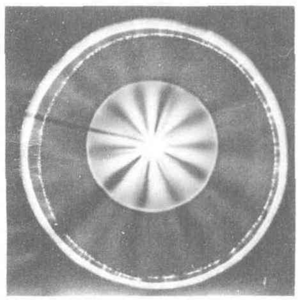
$S=0.037$ cm.
$P=2.8$ cm.



$\times \frac{1}{6}$

$S=0.016$ cm.
$P=7.5$ cm.

$D=10.0$ cm.
$L=7.34$ cm.

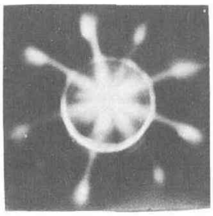


$\times \frac{1}{6}$

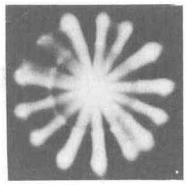
$S=0.050$ cm.
$P=8.0$ cm.

Fig. 12. The R figure on circular cylindrical glass.

1. $D=5.0$ cm. $L=5.0$ cm.

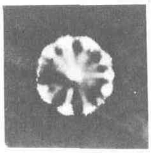
a  $\times\frac{1}{5}$

S : small
$P=6.3$ cm.

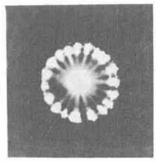
b  $\times\frac{1}{5}$

S : larger than the left one.
$P=6.1$ cm.

2. $D=1.8$ cm. $L=0.50$ cm.

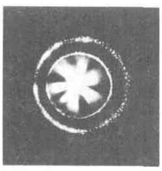
a  $\times\frac{1}{2.1}$

$S=0.006$ cm.
$P=6.3$ cm.

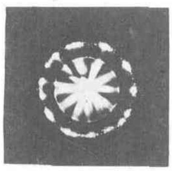
b  $\times\frac{1}{2.1}$

$S=0.052$ cm.
$P=12$ cm.

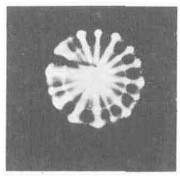
3. $D=18.$ cm., $L=1.00$ cm.

 $\times\frac{1}{2.1}$

$S=0.011$ cm.
$P=12$ cm.

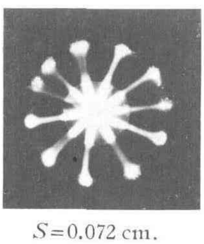
b  $\times\frac{1}{2.1}$

$S=0.034$ cm.
$P=14$ cm.

c  $\times\frac{1}{2.1}$

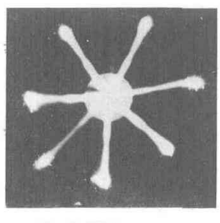
$S=0.072$ cm.
$P=18$ cm.

4. $D=1.8$ cm. $L=2.0$ cm.

 $\times\frac{1}{2.1}$

$S=0.072$ cm.
$S=9.7$ cm.

5. $D=1.8$ cm. $L=3.5$ cm.

 $\frac{1}{2.75}$

$S=0.053$ cm.
$P=6.0$ cm.

Fig. 14. Effects of different electric connections. Dielectric: A circular plate of 10 cm. dia. & 1.5 cm. thickness consisting of 9 sheets of ordinary window glass. Magnification of photographs: $\frac{1}{6}$.

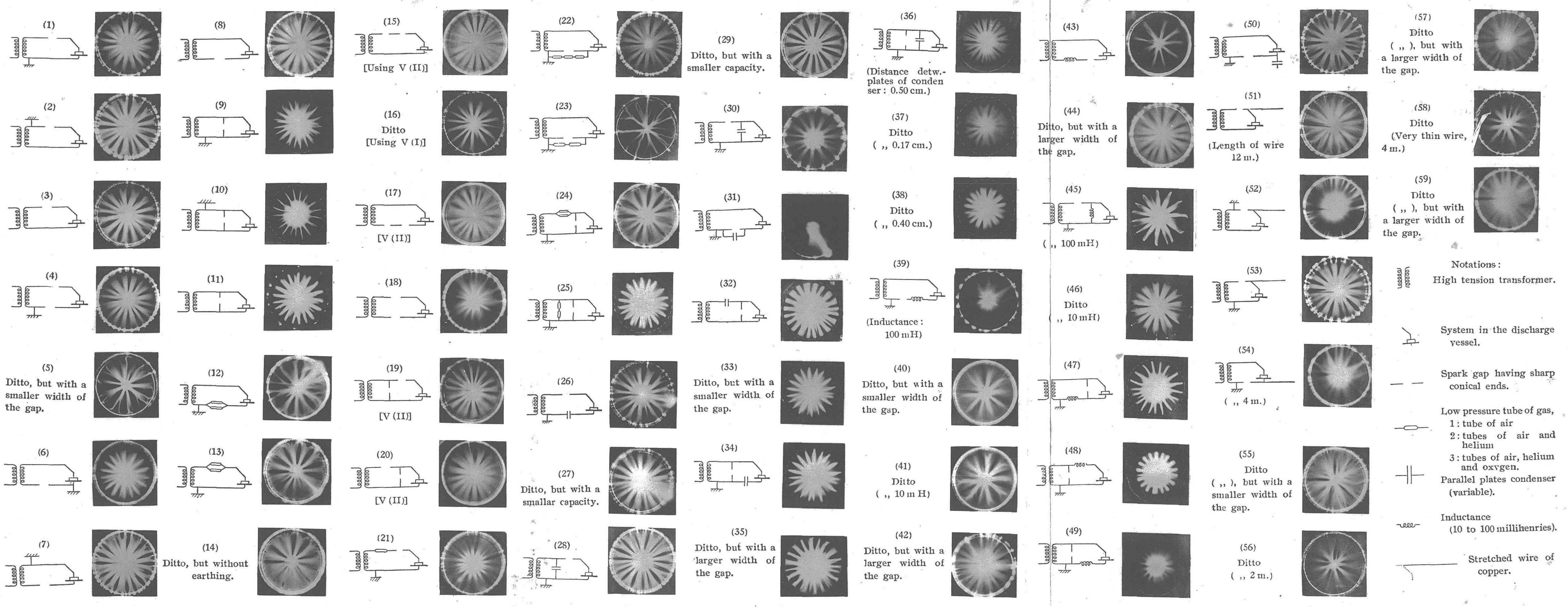
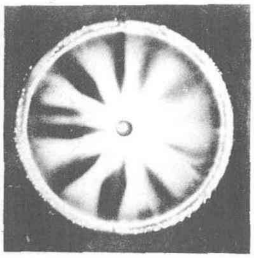
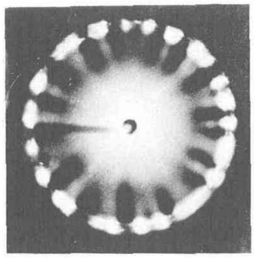


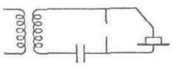
Fig. 15. Effect of different forms of the electrode on the dielectric.
Dielectric: A circular glass plate, $D=10.0$ cm., $L=1.50$ cm.
Electric connection: A (I) without earthing (except No. 3).

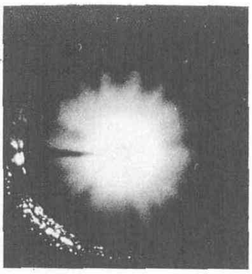
1  $\times \frac{1}{4}$

Dia. of disc: 1.0 cm.
$S=0.020$ cm.
$P=3.7$ cm.

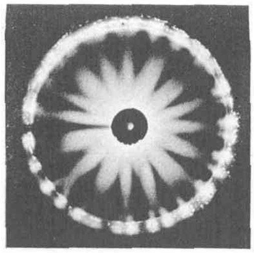
2  $\times \frac{1}{4}$

Dia. of disc: 1.0 cm.
$S=0.024$ cm.
$P=2.3$ cm.

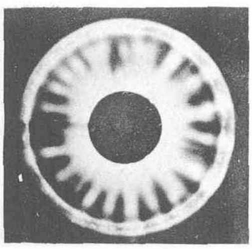


3  $\times \frac{1}{4}$

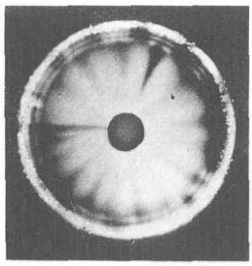
Dia. of disc: 1.0 cm.
$S=0.039$ cm.
$P=2.5$ cm.
C: 0.17 cm. apart.

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

Dia. of disc: 2.0 cm.
$S=0.036$ cm.
$P=3.8$ cm.

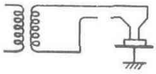
5  $\times \frac{1}{4}$

Dia. of disc: 4.0 cm.
$S=0.035$ cm.
$P=3.2$ cm.

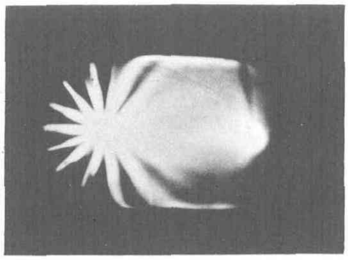
6  $\times \frac{1}{4}$

Cylidrical electrode:
dia. $=2.0$ cm., length $=5.0$ cm.
$S=0.054$ cm.
$P=4.0$ cm.

Fig. 15 (continued). The R figure by two electrodes on the dielectric.



7

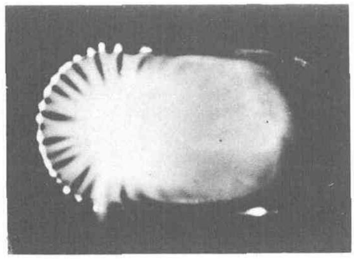


$\times \frac{1}{4}$

$P=5.9$ cm.
$S=0.024$ cm.

Glass :
area $=8^2+\pi 4^2$ cm^2.
thickness $=0.65$ cm.

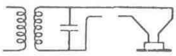
8



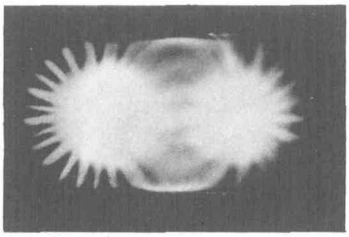
$\times \frac{1}{4}$

$P=4.0$ cm.
$S=0.121$ cm.

Glass : same as 7.



8



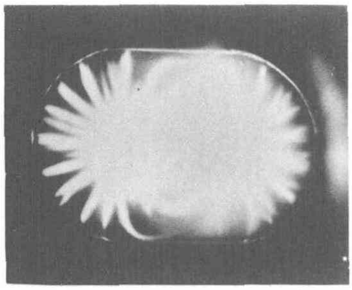
$\times \frac{1}{4}$

$P=4.9$ cm.
$S=0.095$ cm.

Capacity :
dia of disc $=25$ cm.
distance bet. discs
$=1.0$ cm.

Glass : area $=10\times 5+\pi 5^2$ cm^2.
thickness $=0.75$ cm.

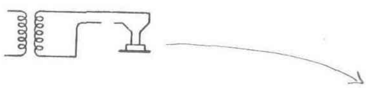
10



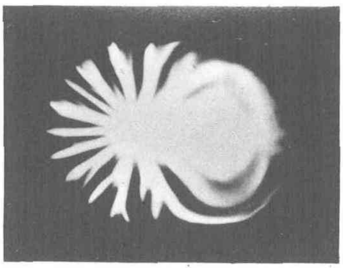
$\times \frac{1}{4}$

$D=5.2$ cm.
$S=0.133$ cm.

Elect. connection : Same as 7.
Glass : same as 10.



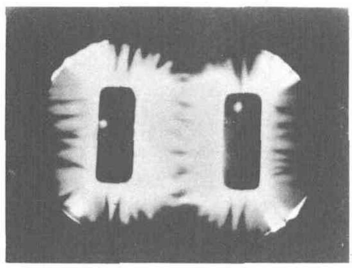
11



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

$P=5.4$ cm.
$S=0.034$ cm.

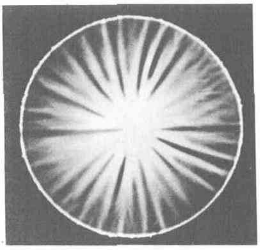
12



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

Glass : area $=10\times 5+\pi 5^2$ cm^2.
thickness $=0.185$ cm.
$P=3.1$ cm.
$S=0.048$ cm.

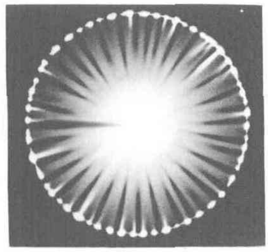
Fig. 18. The R figure on circular plate of bakelite.



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

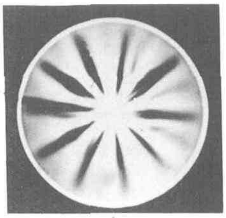
$S=0.034$ cm.
$P=5.0$ cm.

$D=12.0$ cm.
$L=0.315$ cm.



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

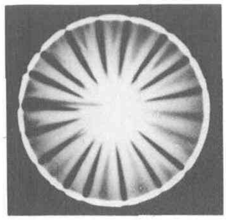
$S=0.073$ cm.
$P=3.3$ cm.



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

$S=0.022$ cm.
$P=5.3$ cm.

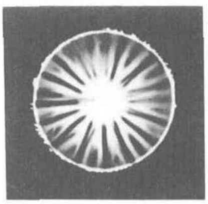
$D=10.0$ cm.
$L=0.630$ cm.



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

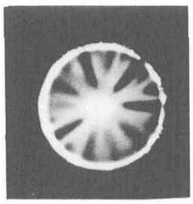
$S=0.139$ cm.
$P=7.0$ cm.

Fig. 19. The radial discharge figure on ebonite.



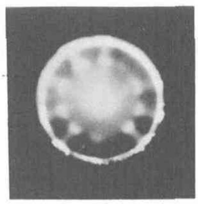
$\times\frac{1}{4}$

$D=7.0$ cm.
$L=0.305$ cm.
$S=0.022$ cm.
$P=5.6$ cm.



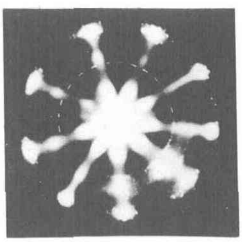
$\times\frac{1}{2}$

$D=3.0$ cm.
$L=0.305$ cm.
$S=0.020$ cm.
$P=7.5$ cm.



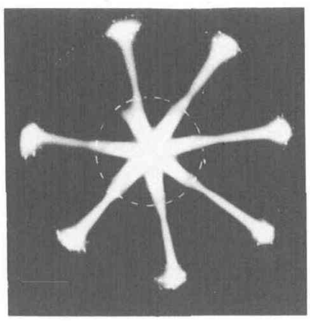
$\times\frac{1}{2}$

$D=3.0$ cm.
$L=0.305$ cm.
$S=0.010$ cm.
$P=4.0$ cm.



$\times\frac{1}{2}$

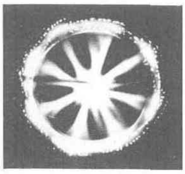
$D=3.0$ cm.
$L=2.0$ cm.
$S=0.044$ cm.
$P=6.0$ cm.



$\times\frac{1}{2}$

$D=3.0$cm.
$L=3.0$ cm.
$S=0.054$ cm.
$P=6.8$ cm.

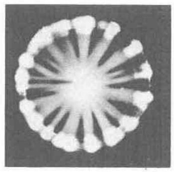
Fig. 20. The R figure on circular plate of various dielectric substance.



×$\frac{1}{4}$

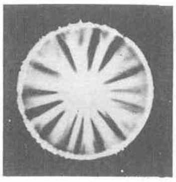
S=0.016 cm.
P=4.4 cm.

Sealing wax:
D=6.0 cm.
L=1.56 cm.



×$\frac{1}{4}$

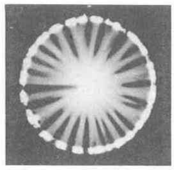
S=0.068 cm.
P=4.6 cm.



×$\frac{1}{4}$

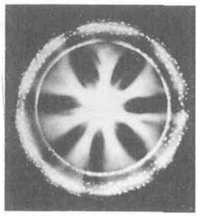
S=0.027 cm.
P=4.4 cm.

Rubber:
D=7.0 cm.
L=0.58 cm.



×$\frac{1}{4}$

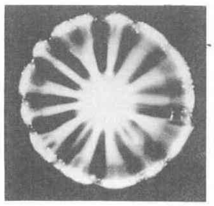
S=0.041 cm.
P=5.2 cm.



×$\frac{1}{4}$

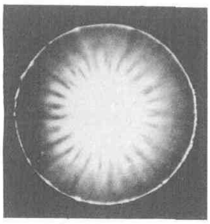
S=0.027 cm.
P=5.0 cm.

Rubber:
D=7.0 cm.
L=1.9 cm.



×$\frac{1}{4}$

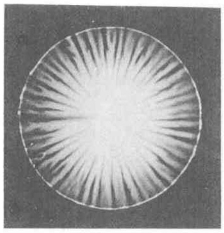
S=0.043 cm.
P=5.1 cm.



×$\frac{1}{4}$

S=0.012 m.
P=3.6 cm.

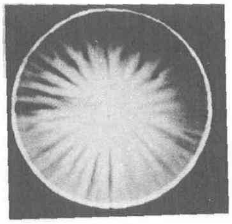
Paper:
D=10.0 cm.
L=0.127 cm.



×$\frac{1}{4}$

S=0.043 cm.
P=5.3 cm.

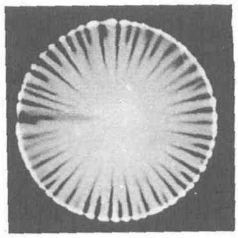
Fig. 20 (continued).



× $\frac{1}{4}$

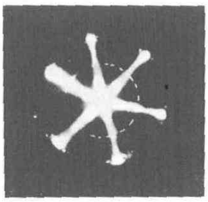
S = 0.010 cm.
P = 5.6 cm.

Celluloid:
D = 8.1 cm.
L = 0.20 cm.



× $\frac{1}{4}$

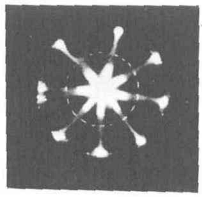
S = 0.034 cm.
P = 5.6 cm.



× $\frac{1}{3}$

S = 0.054
P = 6.0 cm.

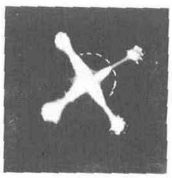
Cork plug:
D = 3.0 cm.
L = 2.2 cm.



× $\frac{1}{3}$

S = 0.067 cm.
P = 7.0 cm.

Cork plug:
D = 2.2 cm.
L = 2.0 cm.

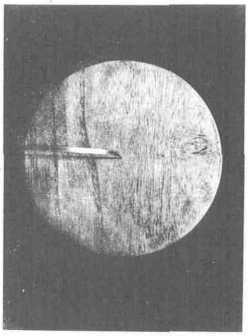


× $\frac{1}{3}$

S = 0.032 cm.
P = 4.9 cm.

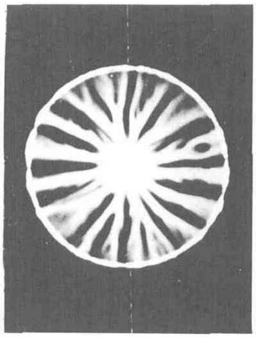
Fig. 21. The R figure on wooden plate.

1. *Kiri:* very soft, porous; a circular plate, $D=10.0$ cm., $L=0.46$ cm.



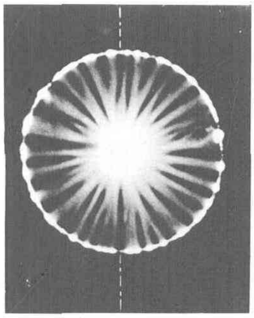
$\times \frac{1}{4}$

The plate just set.



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

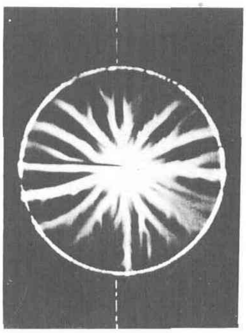
$S=0.008$ cm.



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

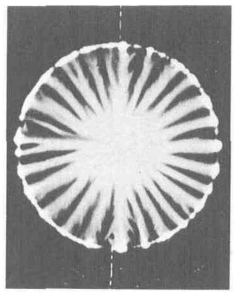
$S=0.046$ cm.

2. *Sen:* porous; a circular plate, $D=10.0$ cm. $L=0.57$ cm.



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

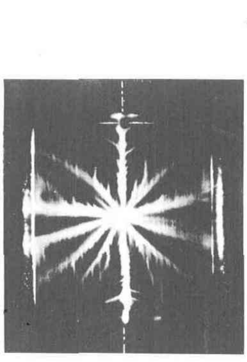
$S=0.008$ cm.



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

$S=0.043$ cm.

3. *Nara:* hard, large porous; a square plate, Side $=10.0$ cm. $L=1.4$ cm.

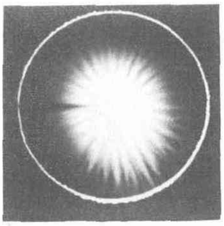


$\times \frac{1}{4}$

$P=7.2$ cm.
$S=0.032$ cm.

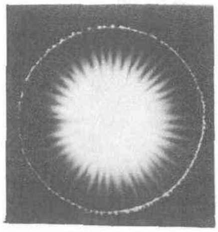
Fig. 22. The R figure generated by the induction coil.

1. A circular glass plate : $D=10.0$ cm.
$L=0.165$ cm.



× $\frac{1}{4}$

Cycles : 40

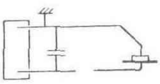


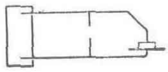
× $\frac{1}{4}$

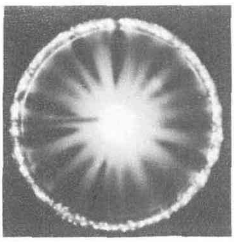
$S=0.004$ cm.
$P=5.4$ cm.

$S=0.018$ cm.
$P=5.4$ cm.

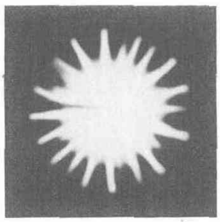
2. A circular glass plate : D$=10.0$ cm., $L=1.5$ cm., Cycles : 40.



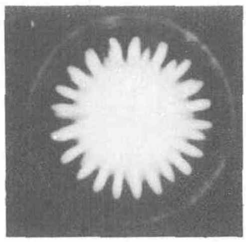




× $\frac{1}{4}$



× $\frac{1}{4}$



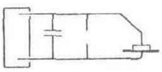
× $\frac{1}{4}$

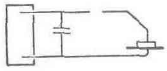
$S=0.024$ cm.
$P=4.2$ cm.

$S=0.070$ cm.
$P=3.7$ cm.

$S=0.098$ cm.
$P=3.1$ cm.

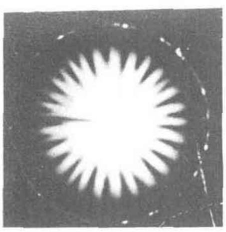
3. A circular plate of bakelite : $D=10.0$ cm., $L=0.315$ cm.



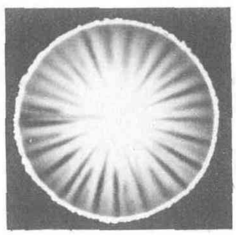


Cycles : 20

Cycles : 40



× $\frac{1}{4}$

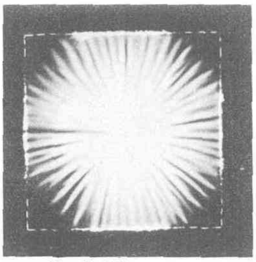


× $\frac{1}{4}$

$S=0.066$ cm.
$P=3.2$ cm.

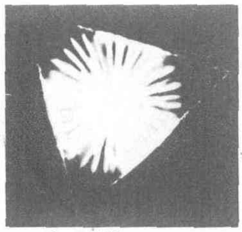
$S=0.022$ cm.
$P=4.5$ cm.

Fig. 23. The R figure on dielectrics of different forms.

(1)

× $\frac{1}{4}$

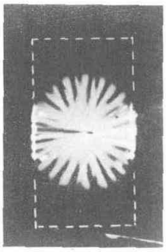
Side : 10 cm.
$L=0.167$ cm.

$S=0.038$ cm.
$P=5.4$ cm.

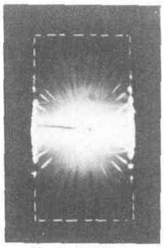
(2)

× $\frac{1}{4}$

Side : 11 cm.
$L=0.165$ cm.

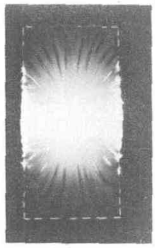
$S=0.010$ cm.
$P=5.3$ cm.

(3) a

× $\frac{1}{4}$

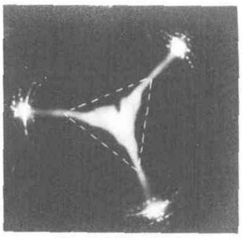
$S=0.010$ cm.
$P=4.3$ cm.

b

× $\frac{1}{4}$

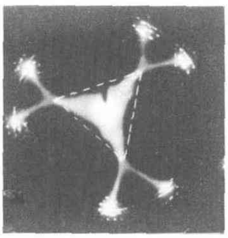
$S=0.074$ cm.
$P=6.2$ cm.

c

× $\frac{1}{4}$

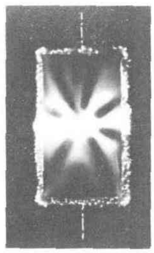
$S=0.096$ cm.
$P=6.1$ cm.

(4) a

× $\frac{1}{4}$

$S=0.032$ cm.
$P=3.8$ cm.

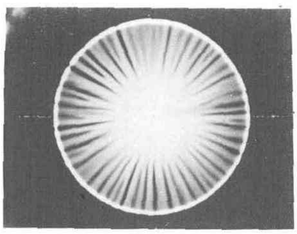
b

× $\frac{1}{4}$

$S=0.044$ cm.
$P=3.8$ cm.

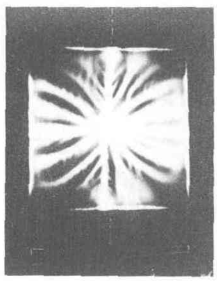
(5)

× $\frac{3}{8}$ Quartz plate:

Side : $\begin{pmatrix} 5.0 \text{ cm.} \\ 2.7 \text{ cm.} \end{pmatrix}$
$L=0.55$ cm.

$S=0.022$ cm.
$P=7.0$ cm.

(6)

× $\frac{1}{4}$

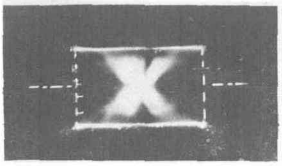
Wedged bakelite :
$D=10.0$ cm.
$L=0.315 \rightarrow 0.15$ cm.
$P=7.2$ cm.
$S=0.072$ cm.

(7)

× $\frac{1}{4}$

Wooden wedge :
Side : 8 cm.
$L=0.62 \rightarrow 0.14$ cm.
$P=5.6$ cm.
$S=0.035$ cm.

Fig. 23 (continued).

(8) a

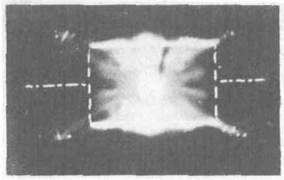


× $\frac{1}{3}$

$S=0.024$ cm.
$P=5.3$ cm.

Ebonite cylinder:
$D=3.0$ cm.
$L=5.0$ cm.

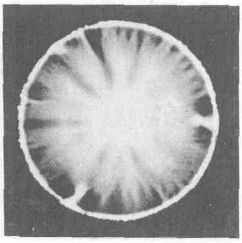
b



× $\frac{1}{3}$

$S=0.078$ cm.
$P=5.3$ cm.

(9) a

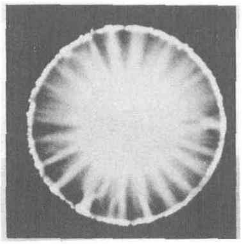


× $\frac{1}{4}$

$S=0.038$ cm.
$P=6.2$ cm.

Glass: $D=10.0$ cm.
$L=0.165$ cm.
Air space: 0.165 cm.

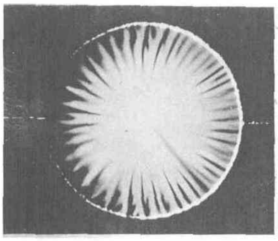
b.



× $\frac{1}{4}$

$S=0.072$ cm.
$P=4.8$ cm.

(10)

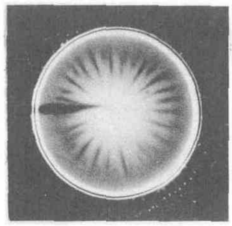


× $\frac{1}{4}$

$S=0.046$ cm.
$P=5.4$ cm.

Glass: $D=10.0$ cm.
$L=0.16$ cm.
Air space: 0.037 cm. → 0.

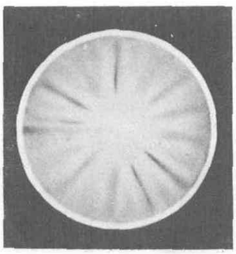
(11)



× $\frac{1}{3}$

$D=6.5$ cm.
$L=0.14$ cm.
Height of vertical edge: 1.7 cm.
$S=0.016$ cm., $P=6.0$ cm.

(12) a

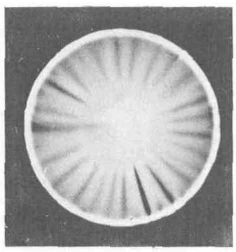


× $\frac{1}{4}$

$S=0.021$ cm.
$P=4.2$ cm.

glass
bakelite

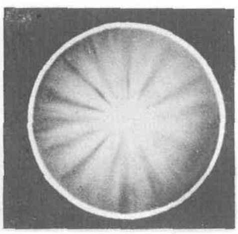
b



× $\frac{1}{4}$

$S=0.042$ cm.
$P=5.2$ cm

(13) a

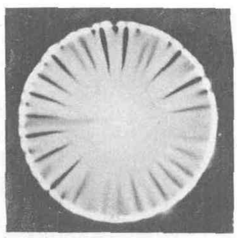


× $\frac{1}{4}$

$S=0.013$ cm.
$P=5.2$ cm.

bakelite
glass

b



× $\frac{1}{4}$

$S=0.040$ cm.
$P=3.9$ cm.