The "Flashing" Phenomena of Neon Lamps

by

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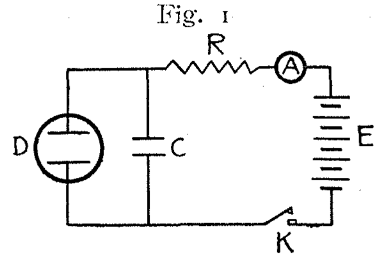
Abstract

The papar deals with the periodic "flashes" of a neon lamp, which are generated by an electric circuit: a condenser, shunted by a great resistance across its terminals, is connected in series with a neon lamp and a battery of suitable electromotive force. By this method, it is possible to get periodic "flashes" of periods up to 40 seconds. The periodic times observed were not generally in accordance with those calculated theoretically. This discrepancy may be due to the leakage of electricity from the lamp and some other parts of the connections, the time necessary for the discharge and to the lag of the spark. The relations between the periodic time of the "flashes", the discharge current and the capacity of the condenser were also investigated for a circuit with a two-electrode valve, and the results were generally in accordance with those obtained by Mitra and Syam in the case of parallel connection of the condenser with the discharge tube.

In Fig. 1, C is a condenser in parallel with a discharge-tube D of low pressure and in series with a battery E and a great resistance R. If the circuit is closed by a key K an intermittent discharge takes place in the tube, and this phenomenon is known to be a source of electric oscillation. Using an air discharge-tube or a neon lamp, many observers have investigated the phenomenon since Gassiot's[1] discovery. Though, as noticed by some observers, the resistance R plays an important rôle in the oscillatory discharge, the condenser has a different significance: it is possible to maintain the oscillatory discharge without any condenser, when the capacity due

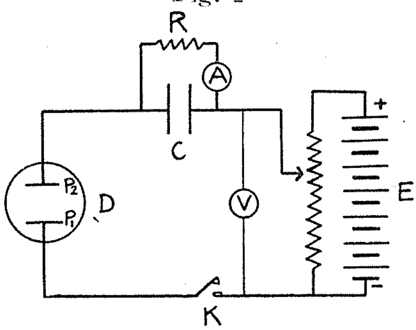
Fig. 1



1 Gassiot: Proc. Roy. Soc. (1863)

to the electrodes of the tube and associated circuits is sufficiently great, as was mentioned by Mitra and Syam.[1] The present paper shows the results obtained with an electric circuit having a condenser in series with a discharge-tube, which can also produce oscillatory discharge of comparatively long period.

Fig. 2



As shown in Fig. 2, a condenser C, shunted by a great resistance R, is connected in series with a neon lamp D. If the circuit is closed by a key K and the applied voltage V is sufficient, a "flash" first appears in the neon tube at the same time as the circuit is closed, and then periodic "flashing" is repeated. By this method, the writer could observe "flashes" of long period, up to about 40 seconds, under the conditions: $V=110$ volts, $C=4\mu F$, $R=6\times10^6\Omega$.

The experimental conditions necessary for "flashing" at regular intervals of time will first be considered. In Fig. 2, A is a microamperemeter and V a voltmeter. It was found that there was a certain value of voltage, below which regular "flashes" could be obtained and above which the lamp was continuously lighted. Table I shows the results obtained for these critical stages. When the current indicated

Table I

Sparking voltage $V_e=93.0$ volts
Extinction voltage $V_b=71.5$ volts

R in ohms.	V in volts	i in mA	$\frac{V-V_b}{R}$, in mA
11.0×10^4	93.0	0.19	0.20
22.0 "	116.4	0.20	0.20
30.0 "	131.5	0.20	0.20
41.0 "	150.5	0.20	0.19
57.9 "	184.0	0.20	0.19

by A (Fig. 2) became greater than about 0.2 mA, the periodic "flashes" could never be obtained whatever the applied voltage. Now,

1 S. K. Mitra and P. Syam: Phil. Mag. **14.** 616 (1932)

at the critical stage, the potential difference between the electrodes of the lamp will be the extinction voltage V_b and that between the plates of the condenser C will be equal to $V-V_b$. If the internal resistance of the lamp is r for this stage, we have

$$V_b/r=(V-V_b)/R=i \qquad (1)$$

and the values calculated by (1) are in good agreement with the readings of the microamperemeter, as is shown in the third and the last column of Table I. Consequently, the critical resistance below which no "flashes" can be obtained, will be given by $\frac{V-V_b}{i}$ or $\frac{(V-V_b)r}{V_b}$ in our case.

For the connection shown in Fig. 1, Taylor and Clarkson[1] obtained critical resistance R_c, using a neon lamp or an air discharge-tube, and it was expressed by

$$R_C=(E-V_B)/k(V_B-V_A) \qquad (2)$$

where E is the charging voltage, V_B the lower oritical voltage, V_A the cathode fall of potential (approximately), and k the conductance of the discharge-tube. However, the critical resistance R in our case was $(V-V_b)r/V_b$ and rather the same as that obtained by Mitra and Syam[2] for their circuit (Fig. I).

Next, keeping the resistance R constant......3×10^5 ohms......the author observed, as described above, the critical current flowing through the resistance for various capacities from 0.25 to $4\mu F$, above which no "flash" appeared. The results obtained for the applied voltage V of 133 volts showed that the critical values were nearly equal to 0.21 mA. which was calculated from equation (1), and that they were independent of the capacity used. The extinction and the sparking voltage of the lamp used were 70 and 89 volts respectively in this case.

Now, we must consider the mechanism of the "flashes" of the lamp for our circuit. In Fig. 2, if the key is closed the positive charge will first flow into the condenser C, and as a result of this the potential at electrode P_2 of the neon tube rises suddenly. As soon as the potential difference between the electrodes P_2 and P_1 reaches the sparking

1 J. Taylor and W. Clarkson: Phys. Soc., Proc. **36**, 269 (1924)
" " " : Phil. Mag. **49**, 336, (1925)

2 S. K. Mitra and P. Syam: loc. cit.

potential V_c of the lamp, the first discharge will start, and if the current coming towards P_2 through the resistance R is not sufficient, the discharge will only be continued until the potential difference between P_1 and P_2 becomes extinction potential V_b. At this time the discharge stops, and the potential difference between the plates of C will be then nearly equal to $V-V_b$, where V is an applied voltage. After this stage, the potential difference between the plates of C will decrease owing to the discharging current through R, and the potential difference between the electrodes of the neon tube will increase again to the sparking potential V_c. Thus the second discharge will be caused.

Let us assume that the charge of the condenser C is q at any time. Then we have

$$q/c=-R(dq/dt) \qquad (3)$$

$$\text{or } \log q=-t/RC+\text{constant}$$

Now, let us assume that

$$q=(V-V_b)C \qquad \text{for} \quad t=0$$

$$q=(V-V_c)C \qquad \text{for} \quad t=T$$

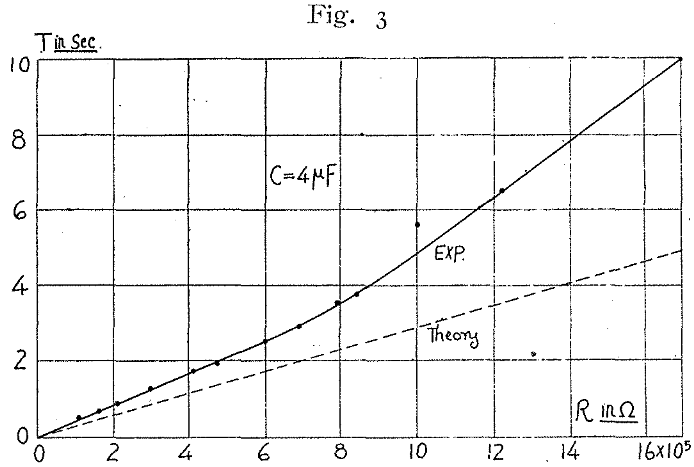
(periodic time of "flashes" approximately).

Then we get

$$T=RC\ \log\{(V-V_b)/(V-V_c)\} \qquad (4)$$

and it will be seen that this is the same as that first obtained by Righi[1] for the connection shown in Fig. 1.

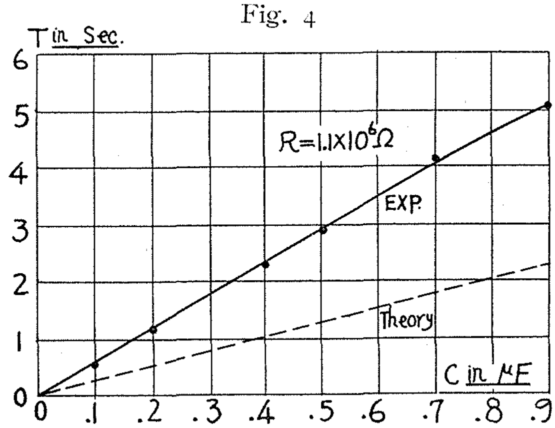
Fig. 3



1 Righi: Rend. d. Accad. d. scienze di Bologna, **103** (1902). K. G. Emeléus: "The conduction of electricity through gases" 19 (1929)

Keeping the applied voltage and the capacity constant......110 volts and $4\mu F$.....the writer observed the "periodic time of flashes" for various values of the resistance R in a dark room to avoid unfavorable disturbances[1]. The results are plotted in Fig. 3 (solid curve). The results obtained when the applied voltage and the shunt resistance were kept at the constant values of 93 volts and 1.1 megohm respectively, and the capacity varied, are shown in Fig. 4 (solid curve). The broken lines drawn in these two figures show the corresponding relations calculated from equation (4), by using the constants $V_c=90$ volts and $V_b=69$ volts in Fig. 3, and $V_c=90.5$ volts, $V_b=70$ volts in Fig. 4 respectively. From these figures, it may be seen that the deviations between the experimental and the theoretical curves in each figure increase as the periodic time of the "flashes" increases. It seems very probable to the writer that this discrepancy is caused by the leakage of electricity from the lamp and some other parts of the connections, besides the time of discharge and the spark lag. However, further experiments on this point will be carried out in near future.

Fig. 4



In order to get a constant current charging the condenser C in Fig. 1, H. Rudolt[2] and E. W. B. Gill[3] used a two-electrode valve instead of the resistance R. Following them, S. K. Mitra and P. Syam[4] also used a diode for the production of the desired values of the charging current by controlling the temperature of the valve filament. The writer too has used the two-electrode valve instead of the resistance R of Fig. 2, as shown in Fig. 5. Though the currents flowing in various branches of the circuit were observed to be of the periodic

1 U. A. Oschwald and A. G. Tarrant: Phys. Soc., Proc. **36**, 241 ; Disc., 249 (1924)

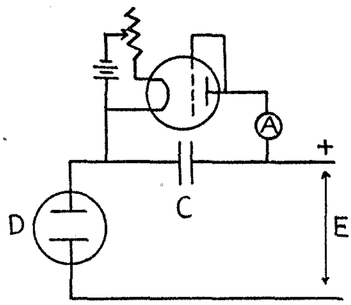
2 H. Rudolt: Archiv. F. Elekt. XIII, **3**, 212, (1924)

3 E. W. B. Gill: Phil. Mag. **8**, 955 (1929)

4 S. K. Mitra and P. Syam: loc. cit.

fluctuations when the lamp was in operation, the fluctuation in the diode-branch was so weak that it was possible to get correct readings of a microamperementer of sensitivity 3.7×10^{-6} ampere.

Fig. 5



Under the conditions $C=1\mu F$ and $V=280$ volts, the writer first investigated the relation between the discharging current through the valve and the periodic time of the "flashes." The results obtained are plotted in Fig. 6 and it may be seen that

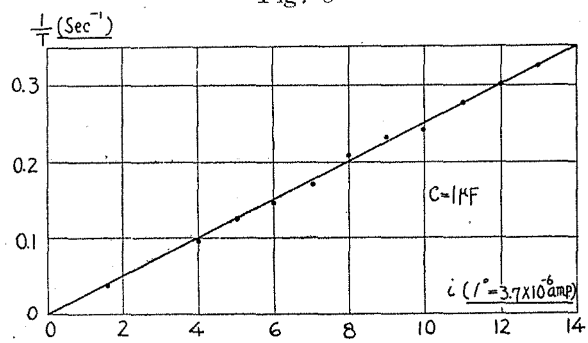
$$i \propto 1/T \qquad (5)$$

It is to be noticed that the relation obtained is similar to that which was obtained by Gill[1] for frequencies from a few to about 150,000 per second. Fig. 7 shows the results obtained for the relation between C and T, and from them it may be learned that

$$T \propto (C+C') \qquad (6)$$

This is nearly in accordance with the relation obtained by Gill[2] and

Fig. 6

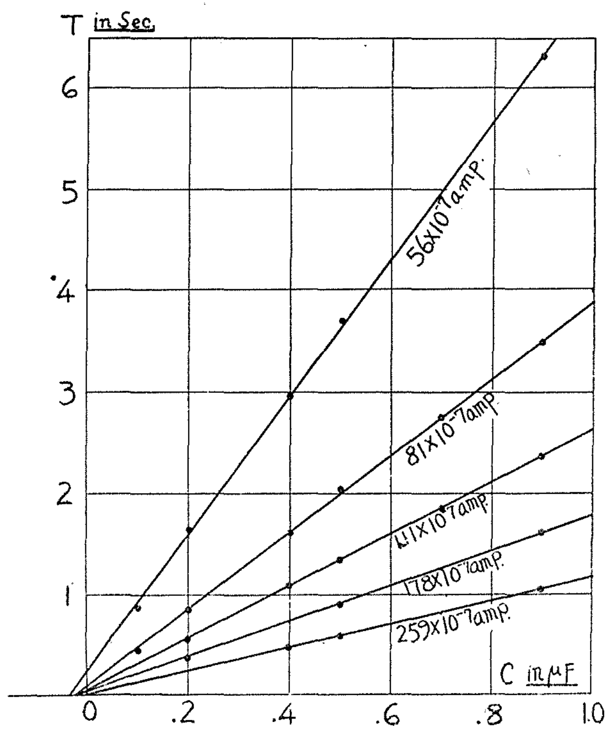


Mitra and Syam[3] for a circuit with a diode, (Fig. 1). According to Gill, C' is constant and depends upon the charging current, being larger for larger currents. According to the results obtained by Mitra and Syam, however, for the frequency between 100 and 1000 p. p. s., C' remains nearly constant, and the small change is in a sense opposite to that

1 E. W. B. Gill: loc. cit.
2 E. W. B. Gill: loc. cit.
3 S. K. Mitra and P. Syam: loc. cit.

obtained by Gill. Fig. 7 shows that the constant C' obtained in our case is comparatively great for a smaller current i and tends to zero as the current increases (readings of microamperemeter A). Clay's[1]

Fig. 7



results show that the C—T line intercepts the C-axis on the positive side; but the lines obtained in the present experiments cut the C-axis on the negative side. These facts found in the present experiments are generally in accordance with the results obtained by Mitra and Syam for the parallel connection of the condenser and the discharge tube.

In conclusion the writer wishes to express his sincere thanks to Professor U. Yoshida for the kind interest he has taken in the research.

1 R. E. Clay: Phil. Mag. **50**, 985 (1925)