July 25, 1950 D. D. KNOWLES ET AL 2,516,326

CAPACITOR CHARGE AND DISCHARGE CIRCUIT FOR STROBOSCOPES

Original Filed May 17, 1935 2 Sheets-Sheet 1

Fig. 1.

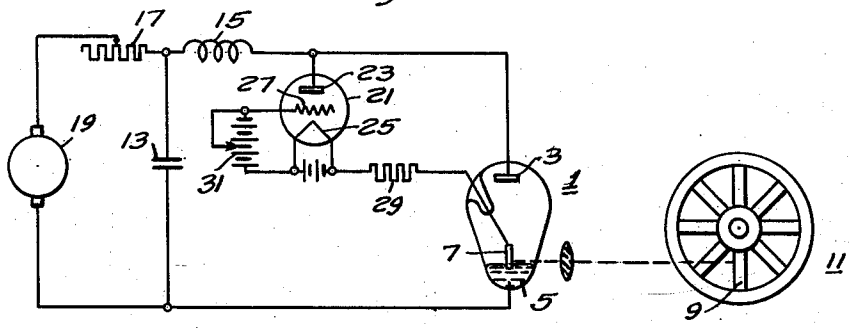

Fig. 2.

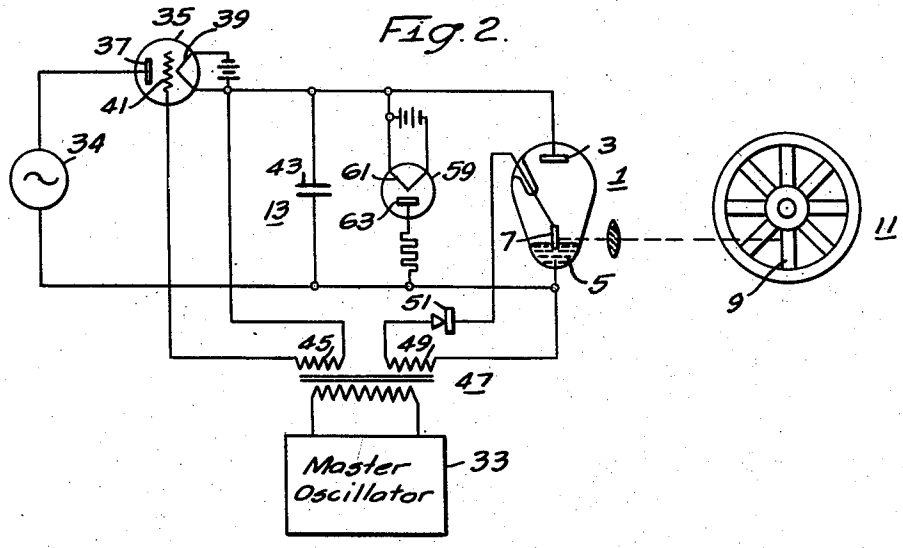

Fig. 3.

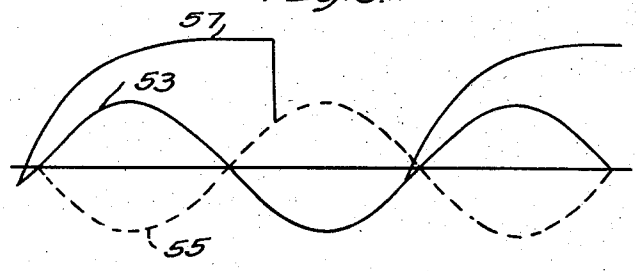

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Fig. 4.

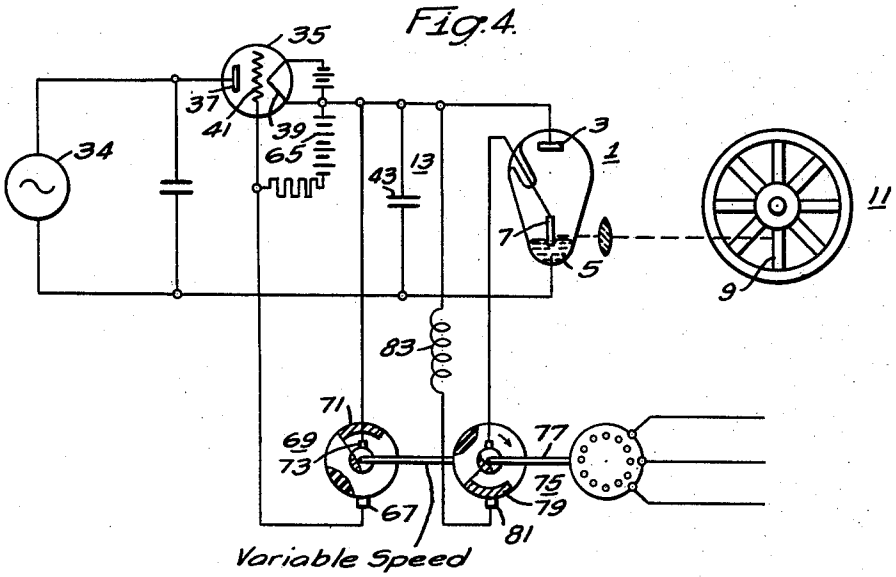


Fig. 5.

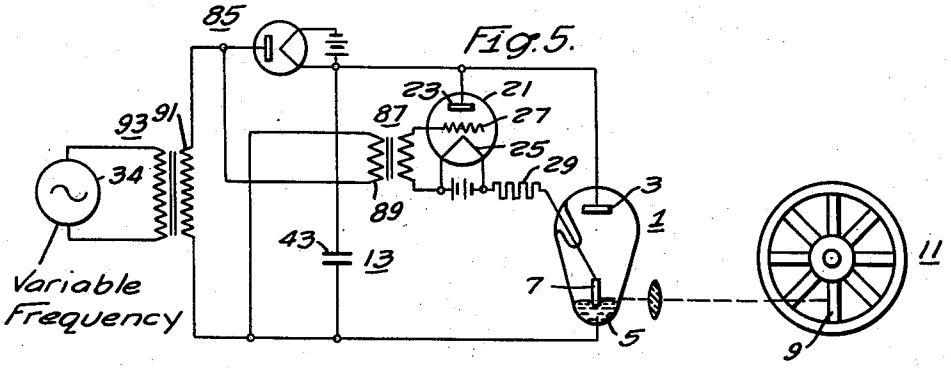
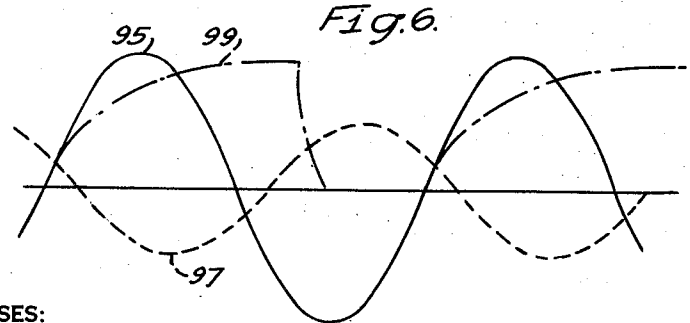


Fig. 6.



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CAPACITOR CHARGE AND DISCHARGE CIRCUIT FOR STROBOSCOPES

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Application September 17, 1941, Serial No. 411,134, now abandoned, which is a division of application Serial No. 120,940, January 16, 1937, now Patent No. 2,310,092, dated February 2, 1943, which in turn is a division of application Serial No. 22,012, May 17, 1935, now Patent No. 2,085,100, dated June 29, 1937. Divided and this application August 30, 1946, Serial No. 694,060

1 Claim. (Cl. 315—200)

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Our invention relates to electric discharge apparatus and it has particular relation to the control of electric discharge devices of the type having a discharge initiating electrode, but not a discharge maintaining electrode such as a keep-alive.

This application is a division of our application Serial No. 411,134, filed September 17, 1941, now abandoned; which is in turn a division of our application Serial No. 120,940, filed January 16, 1937 which has become Patent No. 2,310,092 issued Feb. 2, 1943; which is in turn a division of our application Serial No. 22,012, filed May 17, 1935 which has become Patent No. 2,085,100 issued June 29, 1937.

It is an object of our invention to provide a circuit for controlling the initiation and extinction of the discharge in a discharge device of the mercury pool type that is equipped with a discharge initiating electrode.

Another object of our invention is to provide apparatus for periodically energizing a discharge device of the mercury pool type that is equipped with a discharge initiating electrode.

A further object of our invention is to provide apparatus for energizing and deenergizing, with variable periodicity, a discharge device of the type that is normally completely deenergized.

More specifically stated, it is an object of our invention to provide apparatus for energizing and deenergizing, with precisely determinable periodicity, a discharge device of the type that is equipped with a discharge starting electrode, but not with a discharge maintaining electrode.

In the following discussion and in the claim, we shall refer to a discharge device having a plurality of principal electrodes and a plurality or pair of starting electrodes. Such an expression is drawn with the thought in mind that it shall denominate a discharge device having at least four electrodes, i. e., separate pairs of principal and starting electrodes.

In the preferred structure of the discharge device utilized in the practice of our invention, however, only three electrodes are utilized; an anode, a mercury pool cathode and a starting electrode, preferably composed of boron carbide or silicon carbide, a portion of which is immersed in the mercury. The mercury pool thus serves the double function of cathode and starting electrode cooperative with a boron or silicon carbide electrode. The use of the mercury in the double capacity is, of course, in the interest of economy and convenience and should in no way limit the scope of our invention.

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While in the preferred practice of our invention the above-described discharge device is utilized, it is conceivable that discharge devices of other types may be utilized. For example, the soild starting electrode may be displaced a short distance from the pool and in initiating the discharge a spark may be ignited between the starting electrode and the pool. Moreover, the starting electrode may be a band surrounding the envelope of the discharge device in the region of the pool. It is to be noted, however, that while discharges of the latter types may be utilized, they offer difficulties when used for stroboscopic purposes. To ignite such discharge devices considerable and persistent starting potential is required and as far as we are aware, the operation of such discharge devices is uncertain. However, it should be kept in mind that while the discharge devices of the type incorporating the silicon or boron carbide starting electrode are preferable for stroboscopic work, where the discharge devices of the last-mentioned types have utility and where the teaching of our invention is otherwise followed such use of the discharge devices are equivalent which fall within the scope of our invention.

In accordance with our invention, a source of electrical energy is connected across the principal electrodes of the discharge device and a capacitor is connected in parallel with the principal electrodes. In the circuit of the starting electrodes of the discharge device a valve is connected. The supply of starting current through the valve and the rate of charge and discharge of the capacitor are so timed that the discharge device is energized and deenergized with the desired periodicity. The periodicity may be varied by varying the timing of the supply of starting current or by varying the rate of charge or discharge of the capacitor.

The novel features that we consider characteristic of our invention are set forth with particularity in the appended claim. The invention itself, however, both as to its organization and its method of operation, together with additional

objects and advantages thereof, will best be understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic view showing an embodiment of our invention;

Fig. 2 is a diagrammatic view showing a modification of our invention;

Fig. 3 is a graph illustrating the operation of the apparatus shown in Fig. 2;

Fig. 4 is a diagrammatic view showing a further modification of our invention;

Fig. 5 is a diagrammatic view showing a still further modification of our invention; and

Fig. 6 is a graph illustrating the operation of the apparatus shown in Fig. 5.

Our invention is illustrated herein as utilized in a stroboscope. For stroboscopic purposes, a luminous discharge which can be ignited and extinguished with a precise periodicity is a desideratum. However, as will be manifest from the following description, our invention may also be utilized for other purposes.

The apparatus shown in Fig. 1 comprises a discharge device 1 having an anode 3, a mercury pool cathode 5, and a starting electrode 7 composed of a high resistive material such as boron carbide or silicon carbide, a portion of which is immersed in the mercury 5. When the discharge device 1 is energized, as shall be explained hereinafter, the radiations emitted by the luminous spot formed on the mercury pool surface are projected on the body 9 under observation which is illustrated as the spoke of a rotating wheel 11. The discharge device 1 is energized and deenergized at a periodicity corresponding to the periodicity of the wheel 11 and when the spoke 9 is observed in the illumination emitted by spot, it appears to be at rest. When we refer hereinafter to an electrode or a material of the igniter type we mean thereby an electrode such as 7 or the material of which it is formed. The material in question may be not only of silicon carbide or boron carbide but any other substance which when contacting an electrode and operated by current has the property of facilitating the initiation of an arc between said electrode and another electrode.

A capacitor 13 is connected to the anode 3 of the discharge device 1 through an inductor 15 and directly to the cathode 5 of the discharge device. The capacitor 13 is charged through a resistor 17 from a source 19 which is preferably of the direct current type. The starting electrode 7 is connected to the capacitor 13 through an auxiliary discharge device 21 and the inductor 15. The auxiliary discharge device 21 is preferably of the type having an abrupt characteristic. It is provided with an anode 23, a hot cathode 25 and a control electrode 27 which are immersed in a gaseous medium. The anode 23 is connected to the inductor 15 while the cathode 25 is connected to the starting electrode 7 through a current limiting resistor 29. The control electrode 27 is connected to the cathode 25 through a variable biasing battery 31.

In operation, the auxiliary discharge device 21 is normally deenergized. The capacitor 13 is charged through the resistor 17 in series therewith. When it attains a difference of potential predetermined by the magnitude of the bias in the control circuit of the auxiliary discharge device the latter is energized and a pulse of current is transmitted between the starting electrode 7 and the mercury pool 5. A discharge is, therefore, initiated between the principal electrodes 3 and 5 of the main discharge device 1 which persists for an interval of time predetermined by the relative magnitudes of the inductor 15 and the capacitor 13. The capacitor 13 is discharged when the main discharge device 1 is energized and when the main discharge device is extinguished, the capacitor is recharged and the above-described process is repeated. Since the electrode 7 and the mercury 5 both cooperate to produce an arc, they may be designated together as a plurality of starting electrodes.

The excitation of the main discharge device 1 is periodic. The periodicity of the excitation may be varied either by varying the resistor 17 in series with the capacitor 13, and thus varying the rate of charging of the capacitor, or by varying the biasing battery in the control circuit of the auxiliary discharge device, and thus varying the magnitude of the charge which is to be applied to the capacitor to produce excitation of the auxiliary discharge device. In the practice of our invention, either of these elements is so varied that the frequency of discharge of the main discharge device corresponds to the frequency of movement of the body 9 under observation. This correspondence is attained by subjecting the body 9 to the illumination from the discharge device and by slowly varying the resistor or the control battery until the body appears to be at rest.

In the apparatus shown in Fig. 2, the proper periodicity of illumination is attained by utilizing the output of a master oscillator 33, the frequency of which may be varied. Here again, a capacitor 13 is connected between the mercury pool 5 and the anode 3 of the main discharge device 1. The capacitor 13 is charged from a source 34 through an auxiliary discharge device 35 of the type having an anode 37, a cathode 39 and a control electrode 41. If the source 34 utilized for charging is of the alternating current type, the auxiliary discharge device 35 should preferably be of the asymmetric type and should be so connected to the capacitor 13 that the capacitor plate 43 which is connected to the anode 3 of the main discharge device 1 is charged positive.

The excitation of the auxiliary discharge device 35 is controlled from the master oscillator 33. A potential provided by the master oscillator 33 is impressed between the control electrode 41 and the cathode 39 through a secondary section 45 of a suitable transformer 47 and the discharge device 35 is energized at a frequency corresponding to that of the master oscillator.

The master oscillator 33 also provides current impulses for energizing the main discharge device. For this purpose, another secondary section 49 of the transformer 47 is connected between the starting electrode 7 and the mercury pool 5 of the main discharge device 1 through a suitable rectifier 51. Half-wave impulses produced by the oscillator 33 are thus transmitted through the starting electrode 7 of the main discharge device 1 and periodically initiate the discharge in the main discharge device, the anode-cathode potential being supplied by the capacitor 13.

To provide for precise operation of the main discharge device 1, the secondaries 45 and 49 of the oscillator transformer 47 are so wound that the initiating discharge is only transmitted through the starting electrodes of the main discharge device after the capacitor 13 has been charged and when the auxiliary discharge de-

vice 35 blocks the charging current. Preferably, the potential supplied to the control circuit of the auxiliary discharge device 35 is in opposite phase to the potential supplied between the starting electrodes 7 and 5 of the main discharge device 1, to accomplish this purpose.

The operation of the apparatus is illustrated in Fig. 3. In this view, the full-line sine curve 53 represents the control potential supplied by the oscillator 33 to the auxiliary discharge device 35. The broken-line sine curve 55 represents the control potential supplied between the starting electrodes 7 and 5. It will be noted that the full-line and the broken-line curves 53 and 55 are in opposite phase. The potential difference impressed on the capacitor 13 is represented by the full-line curve 57 rising above the sine curves. If the resistance in series with the capacitor 13 is comparatively small, the capacitor may be charged during the interval corresponding to a single half-wave of the potential supplied by the oscillator 33 as illustrated. During the succeeding half cycle, sufficient current is transmitted between the starting electrode 7 and the mercury pool 5 of the main discharge device to energize the main discharge device 1 and the main discharge device having been energized, the capacitor 13 is discharged.

A rectifier 59 is connected between the anode 3 and the cathode 5 of the main discharge device 1 to prevent the current in the main discharge device from oscillating. The cathode 61 of the rectifier 59 is connected to the anode 3 of the main discharge device 1 and the anode 63 of the rectifier is connected to the mercury pool 5. If there is a tendency to oscillate, the rectifier network absorbs the oscillations.

In the apparatus shown in Fig. 4, the capacitor 13 connected between the anode and the cathode of the main discharge device is charged during a predetermined interval of time and after it has been so charged, it is discharged during a later interval of time.

For this purpose, an auxiliary discharge device 35 similar to the discharge device utilized in the modification shown in Fig. 2 is provided in series with the power source 34 and the capacitor 13. The cathode 39 of the auxiliary discharge device 35 is connected to the plate 43 of the capacitor 13 that is to be charged positive and the anode 37 is connected to the source. Normally, the discharge device 35 is in non-conductive condition by reason of the functioning of a biasing battery 65 connected between the cathode 39 and the control electrode 41 which maintains the control electrode 41 at a negative potential relative to the cathode 39. The control electrode 41 is moreover connected to a brush 67 which contacts a rotating commutator 69 provided with a conducting segment 71 of predetermined length. The segment 71 is directly connected to the cathode 39 through a second brush 73.

As the commutator is rotated, the first brush 67 comes into contact with the segment 71 for a predetermined interval of time and during this interval of time, the control electrode 41 is at the same potential as the cathode 39. The discharge device, therefore, passes current to charge the capacitor 13. The total resistance in series with the capacitor is comparatively low and the capacitor is charged in a short interval of time.

To ignite the main discharge device 1, a second commutator 75 mounted on the shaft 77 of the commutator 69 and rotating in synchronism is provided. The second commutator 75 is provided

with a conducting segment 79 which is directly connected to the starting electrode 7. A brush 81 in contact with the surface of the commutator 75 is connected to that plate 43 of the capacitor 13 which is charged positive through a suitable impedance 83. The impedance properly regulates the starting impulse of current when it is transmitted.

The conducting segment 79 on the last-mentioned commutator 75 is displaced in phase with respect to the conducting segment 71 of the first-mentioned capacitor 69. It operates when contacted by its brush 81 to discharge the capacitor 13, after it has been charged, through the starting electrode 7 and the mercury pool 5. The charge on the capacitor 13 is not exhausted by the impulse transmitted through the starting electrode 7 and the residual difference of potential is of sufficient magnitude to cause the main discharge device 1 to become energized. When the main discharge device is energized, the starting electrode circuit is shunted out. It will be seen from the above description that a small portion of the charge on the capacitor is utilized to ignite the discharge device after which the residual charge is utilized in producing the main discharge. A single capacitor serves the double function of providing starting current and discharge potential. The periodicity of the discharge produced in the main discharge device may be varied by varying the speed of the commutators 69 and 75.

In the apparatus shown in Fig. 5, the capacitor 13 connected between the anode 3 and the cathode 5 of the main discharge device 1 is charged through a half-wave rectifier 85 from an alternating source 34. To discharge the capacitor 13 through the starting electrode 7, an auxiliary discharge device 21, similar to the discharge device utilized in the embodiment shown in Fig. 1, is provided in series with the starting electrode 7 and the cooperative mercury pool 5. The cathode 25 of the auxiliary discharge device 21 is connected through the limiting resistor 29 to the starting electrode 7, and the anode 23 is connected to the positive plate 43 of the capacitor 13.

The control circuit of the auxiliary discharge device 21 is supplied from a transformer 87, the primary 89 of which is connected across the secondary 91 of the main power supply transformer 93. However, the terminals of the primary 89 of the auxiliary transformer 87 are so arranged with respect to the terminals of the secondary 91 of the main transformer 93 that the potential supplied in the control circuit of the auxiliary device 21 is displaced in phase with respect to the potential supplied by the secondary 91 of the main transformer.

In Fig. 6, the operation of the apparatus is illustrated graphically. The full-line sine curve 95 represents the potential supplied by the main transformer 93 and the broken-line sine curve 97 represents the control potential supplied by the auxiliary transformer. Since the resistance in series with the capacitor 13 and the half-wave rectifier 85 is small, the capacitor 13 is quickly charged during the half cycles during which the potential output of the main transformer 93 is such that rectifier 85 is conductive. The dot-dash curve 99 represents the charging operation. After the capacitor 13 is charged and the charging operation is discontinued, the control potential supplied to the auxiliary discharge device 21 attains a value of sufficient magnitude to energize the auxiliary discharge device. The capacitor 13 is then discharged through the discharge device

21 and through the starting electrode 7 of the main discharge device 1. The main discharge device 1 is immediately energized under the influence of the residual potential difference impressed on the capacitor and it remains energized until the capacitor is discharged. After this, the capacitor is recharged and the process is repeated. It is to be noted that here again a single capacitor 13 is utilized for the double purpose of supplying starting current and ignition potential.

Our invention has been herein shown and described as utilizing a main discharge device 1 in which the cathode is a mercury pool. The principal advantage of such a discharge device resides in the intense cathode spot which forms on the surface of the cathode when the discharge device is energized. Discharge devices having cathodes of other types have been utilized by us and on the surface of the cathode in certain of these discharge devices a cathode spot also forms. We have found this is particularly true of discharge devices in which the cathode is composed of such metals as cadmium, zinc, sodium, potassium, or alloys of these metals. In the claim which follows, we shall refer to a discharge device having a mercury cathode or a mercury pool cathode.

We intend by this expression to cover the general case of a cathode on which a cathode spot forms and the expression shall be taken to include cathodes of all types on which a cathode spot forms.

We claim as our invention:

An electrical system comprising a capacitor; means for charging said capacitor, a discharge channel for said capacitor including an asymmetrically conductive main electric discharge device, said channel having a tendency to cause the current in said main discharge device to oscillate thereby to tend to produce back discharge of said capacitor through said discharge device; and unidirectional by-pass means connected in shunt with said discharge device in inverse conductive direction thereto to prevent said current in said main discharge device from oscillating.

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The following references are of record in the file of this patent:

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Number	Name	Date
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