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ELECTRIC SYSTEM

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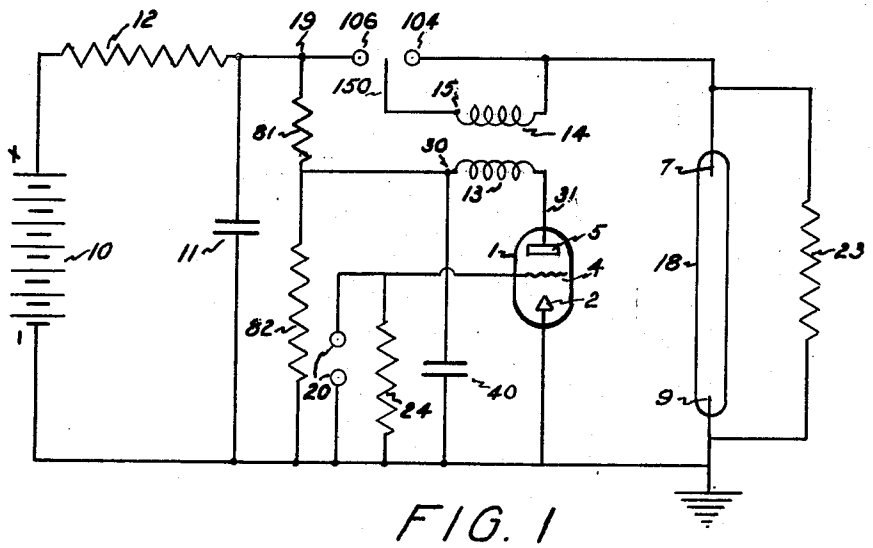


FIG. 1

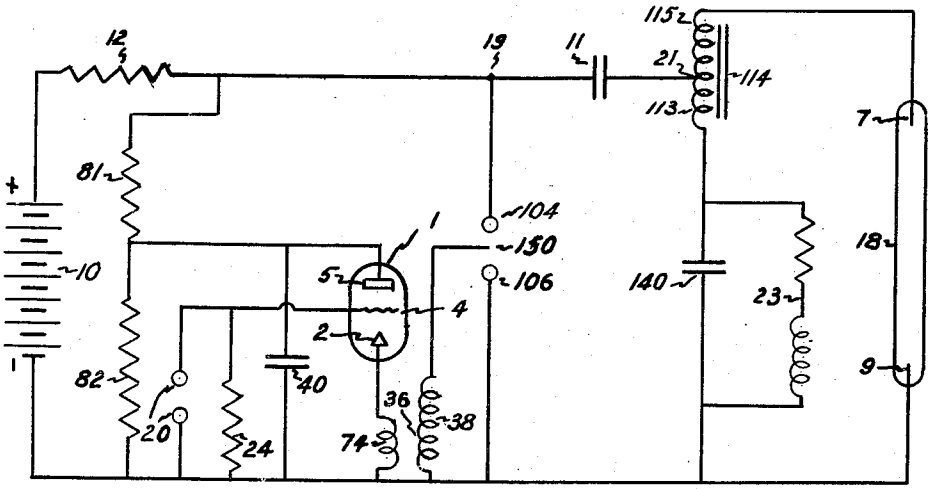


FIG. 2

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ELECTRIC SYSTEM

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9 Claims. (Cl. 315—180)

The present invention, though having fields of more general usefulness in electric systems, is particularly related to systems in which a flash condenser is discharged through the gaseous medium of a gaseous-discharge device for such purposes as to produce a single flash or a repetition of flashes in flash-photography and stroboscopic work.

The most efficient flash-producers of the above-described character in use today embody flashlamps, commonly called flashtubes, provided with not only an anode electrode and a cathode electrode between which to send the flash-producing current through the gaseous medium, but also a high-voltage starting, control or trigger electrode. The necessity for employing the trigger electrode introduces complexities and increases the size of the gaseous-discharge device, but the proposals that have heretofore been made for eliminating it have not been satisfactory.

An object of the present invention, therefore, is to provide a new and improved electric system of the above-described character embodying a two-electrode gaseous-discharge device.

Another object is to provide a new and improved flash-producing system of the above-described character embodying a flash device unprovided with a starting or control electrode.

A further object is to provide a new and improved condenser-discharge circuit of the above-described character having a three-electrode triggering spark-gap gaseous-discharge device in series with the gaseous-discharge tube.

Another object is to provide a new and improved electric system of the above-described character in which the discharge of a condenser through a two-electrode gaseous-discharge device is under the control of a three-electrode spark gap.

Another object still is to reduce the expense of systems of the above-described character.

Other and further objects will be explained hereinafter, and will be particularly pointed out in the appended claims.

The invention will now be more fully explained in connection with the accompanying drawings, in which Fig. 1 is a diagrammatic view of circuits and apparatus arranged and constructed according to one embodiment of the invention; and Fig. 2 is a similar view of a modification.

A main-discharge flash condenser or capacitor **11**, shown charged from a direct-current source, illustrated as a battery **10**, through a current-limiting charging impedance **12**, is shown series-connected in a discharge circuit to the anode electrode **7** and the cathode electrode **9** of a normally non-conducting two-electrode gaseous-discharge device, such as a space-discharge flashtube or flashlamp **18**. The condenser **11** may be charged to a voltage of from 200 to 2000 volts. The flashes are produced by discharging the condenser **11**, after it has become charged, through the discharge circuit and through the gaseous medium of the lamp **18**, between the anode **7** and the cathode **9**.

The three electrodes of the spark-gap gaseous-discharge device are shown comprising two principal electrodes **104** and **106** and a starting, triggering or control electrode **150**. In air, the distance between the principal electrodes **104** and **106** may be, say, 3/16 to 1/4 of an inch. The spark gap will then be of very low impedance compared to the several-ohms' impedance of typical flash lamps.

As the energy lost in the spark gap itself is negligible, this insures that the energy shall be dissipated in the flashlamp **18**.

One of the terminals of the condenser **11** is connected permanently to one of the electrodes of the gaseous-discharge device **18**, the other terminal of the condenser **11** is connected permanently to one of the principal electrodes of the spark gap, and the other electrode of the gaseous-discharge device **18** is connected permanently to the other principal electrode of the spark gap.

Because of the dielectric properties of the normally deionized air in the space between the spark-gap electrodes **104** and **106**, the direct-current source **10** will charge the condenser **11** through the impedance **12** without any of its energy traversing that space. A difference of potential will therefore be established between the spark-gap electrodes **104** and **106** during the charging of the condenser **11** before each flash. The impedance **12** should be designed sufficiently large so that, after the creation of the spark between the principal electrodes **104** and **106**, further current flow between them will be prevented until after the air of the spark gap shall have again become deionized. The impedance **12** should, however, be small enough to permit of the condenser **11** becoming recharged with energy from the direct-current source **10** in time for the next flash.

Referring now more particularly to Fig. 1, the principal electrodes **104** and **106** are shown connected in the condenser-discharge circuit, in series with the flashlamp **18**. The principal electrode **104** is shown connected to the anode **7**, and the principal electrode **106** to a terminal **19** connecting one side of the condenser **11** to the current-limiting impedance **12**.

The secondary winding **15** of a triggering transformer **14** is shown connected to the starting electrode **150**. A high-voltage pulse is designed to be impressed momentarily upon the secondary winding **15**, at a suitable time, in order to impress a high-potential stimulus or charge on the triggering electrode **150**. The air in the vicinity of the starting electrode **150**, between the principal spark-gap electrodes **104** and **106**, becoming thereby rendered conducting by ionization, a high-voltage low-energy spark will jump across between the principal spark-gap electrodes **104** and **106**.

Upon the spark gap becoming thus ionized, the voltage of the condenser **11** becomes impressed across the lamp **18**. If the lamp **18** is so designed that its breakdown voltage shall be less than the voltage to which the condenser **11** has been charged, the lamp **18** will be rendered conducting. Upon the lamp **18** becoming thus conducting, the condenser **11** will suddenly discharge therethrough, between the anode **7** and the cathode **9**.

The necessarily high-peak discharge currents are thus effectively controlled by a simple inexpensive triggering three-electrode spark gap. As the additional high-voltage trigger electrode that is customarily employed with gaseous-discharge flashlamps is unnecessary according to the present invention, the connections become simplified, and it becomes possible to employ a gaseous-discharge device **18** of smaller size.

The momentary voltage pulse for triggering the spark gap may be induced in the secondary winding **15** by supplying a corresponding voltage pulse for energizing the primary winding **13** of the transformer **14**. This may be effected in any desired way, as by discharging a small trip condenser **40** through the primary winding **13**, in series with a normally non-conducting trigger tube **1**, by way of lead wires **30** and **31**. Because of the normally non-conducting character of the trigger tube **1**, it provides a normally open switching device. The impedance of the lead wires **30** and **31**, which may be fairly long, should not be too great compared to the impedance of the primary winding **13**. The condenser **40** may be of the order of 0.1 microfarad, compared to the order of 10 microfarads for the condenser **11**.

The condenser **40** may be charged from any desired direct-current source, such as a bleeder resistor. The bleeder resistor is shown comprising two resistor sections **81** and **82** connected in series across the battery **10** to constitute a voltage divider for adjusting the voltage on the condenser **40**. The free terminal of the resistor **81**

is connected to the terminal 19, at one side of the condenser 11, and the free terminal of the resistor 82 is connected to the other side of the condenser 11.

The trigger tube 1 should be of a type capable of passing high-peak currents. It may, for example, be of the normally non-conducting cold-cathode gaseous-discharge type illustrated and described in Letters Patent 2,185,189, 2,202,166 and 2,201,167, issued January 2 and May 21, 1940. It may comprise an evacuated glass envelope filled with a suitable gas, such as neon, or any of the noble gases, such as argon or helium. The tube 1 is shown containing several electrodes, namely, a solid cold cathode 2, an anode or plate 5, and one or more grids 4. As explained in the said Letters Patent, the scurce of the electrons is a bright cathode spot on the surface of the cathode 2. The moment of discharge of the condenser 40 through the primary winding 13 is controlled by the potential on the grid 4 of the trigger tube 1. An impedance 24, illustrated as a resistor, is shown connected between the cathode 2 and the grid 4, in parallel with terminals 20.

When it is desired to trigger the flashes of the lamp 18, a potential is applied to the control-grid electrode 4 through the terminals 20. This results in closing the said normally open switching device, and triggers the tube 1 to enable the trip condenser 40 to discharge therethrough and through the primary winding 13. The voltage and the power necessary to effect this result depend upon the design of the particular tube 1 employed.

A high impedance 23, shunted across the flashlamp 18, insures that there saall be no voltage across the lamp 18 until the spark gap is triggered. This impedance, which may be on the order of a megohm, is low compared to the leakage resistance across the lamp 18 when it is non-conducting, but high compared to the impedance of the lamp 18, when it is ionized.

It is desirable to have the lamp dimensions and the gas pressure such that the breakdown voltage of the flashtube 18 shall be appreciably greater than the voltage to which the discharge condenser 11 is charged, say, several times as great. It has been found that the lamp 18 then converts a greater proportion of the energy in the condenser 11 into useful light.

In the system of Fig. 1 the breakdown voltage of the lamp 18 must be less than the voltage to which the condenser 11 is charged. In the system of Fig. 2, however, this limitation in lamp design is removed, which permits of the use of a more efficient lamp. In this Fig. 2, the three-electrode spark gap is shown controlling one of the circuits disclosed in application, Serial No. 679,983, filed June 28, 1946, embodying a saturable transformer 114. The saturable transformer 114 is shown comprising primary and secondary inductance windings 113 and 115. One end of the winding 113 is connected to one end of the winding 115 at a common terminal 21. The other end of the winding 115 is shown connected to the anode 7 of the lamp 18. The other end of the winding 113 is shown connected to the cathode 9 of the lamp 18 through a condenser 140, shown connected in parallel with the impedance 23. The voltages of both the primary and secondary windings 113 and 115 of the transformer 114 are thus connected in series circuit with the flashtube 18.

Since the secondary winding 115 of the transformer 114 is series-connected in the condenser-discharge circuit, it is desirable, in order to attain high efficiency and a discharge time that shall not be too long, that its impedance be low with respect to the impedance of the lamp 18 at the time of discharge of the condenser 11. For a reasonable discharge current in the tube 1, on the other hand, it is desirable that the impedance of the primary winding 113 be reasonably high at the time that the triggering impulse is applied to the primary winding 113 and prior to the discharge of the condenser 11.

With a primary winding the effective impedance of which is high at the time of the discharge of the condenser 40, moreover, it is possible to arrange that the impedance of the lead wires 30 and 31 to the transformer primary winding 113, which may be fairly long, shall not be too great compared to the impedance of this primary winding 113. The required low impedance of the secondary winding 115, at the time of the discharge of the condenser 11, and the required high impedance of the primary winding 113, at the time that the triggering impulse is applied to the primary winding 113, prior to the discharge of the condenser 11, may be attained by providing the transformer 114 with an iron core that saturates at the time when the main condenser 11 discharges through the transformer in response to the production of the triggering voltage across the secondary winding 115. It is because of the saturable character of the core of the transformer 114 that a low impedance is offered to the discharge of the condenser 11 through the discharge circuit including the gaseous-discharge device 18. The permissible saturated inductance of the secondary winding 115 of the transformer 114 may be computed from the well-known equations governing the transient behavior of a series-discharge circuit of resistance, inductance and capacitance.

The impedance of a typical flashlamp 18, for example, 30 centimeters long and 4 millimeters inside diameter, and filled with xenon at 10 centimeters pressure of mercury, may be 3 or 4 ohms. A typical condenser 11 may be of 10 microfarads capacity. The transient in the series-condenser discharge circuit comprising the condenser 11, the secondary winding 115, the spark gap and the lamp 18 will depend on the relative proportions of the resistance, the inductance and the capacitance.

The saturated inductance of the secondary winding 115 of the transformer 114 may be as great as 40 microhenries without seriously affecting the duration of the flash or the peak current in the condenser-discharge circuit. If the resistive component of the impedance of the secondary winding 115 is low compared to 4 ohms, the efficiency will still be good, and the operation will be comparable to the operation that takes place without the transformer 114. Under the above conditions, the operation will be satisfactory so long as

$$L=\frac{R^2C}{4}$$

where L is the inductance of the condenser-discharge circuit, R is its resistance, and C is its capacitance. In most practical cases, it is permissible to tolerate even the relation:

$$L=R^2C$$

A typical transformer 114 may have a closed iron core of 0.094 square inch cross section and 4 inches effective length, and may be constituted of a good grade of thin silicon-steel laminations. On this core may be wound a secondary winding 115 of 50 turns and a primary winding 113 of 5 turns. When the iron core is saturated, the inductance of the primary winding 113 may be of the order of 0.20 microhenry, and that of the secondary winding 115 of the order of 20 microhenries. The saturated inductance of 20 microhenries for the secondary winding 115 is well below the value 40 microhenries before referred to. When the iron core is not saturated, the inductance may be 100 times as great, corresponding to a primary-winding inductance of 20 microhenries. Since ordinary cable has an inductance on the order of 0.2 microhenry per foot, this value is large enough so as not to introduce troubles due to the impedance of the lead wires.

One side of the condenser 11, as in the system of Fig. 1, is connected to the terminal 19. The principal spark-gap electrode 104, however, is also connected to the terminal 19, and the other side of the condenser 11 is connected to the terminal 21 of the saturable transformer. The main-discharge capacitor 11 is charged from the direct-current source 10, not only through the current-limiting impedance 12, as in the system of Fig. 1, but also through the saturable-transformer winding 113 and the impedance 23.

The starting electrode 150 is shown in Fig. 2 as energized, in order to impress a high-potential stimulus or charge therein, by the secondary winding 38 of a high-ratio triggering transformer 36, which may be of the spark-coil type. The primary winding 74 is shown connected in series with the cathode 2.

As in the system of Fig. 1, the small trip condenser 40 discharges through the primary winding 74 of the transformer 36, in series with the trigger tube 1, and the moment of discharge of the condenser 40 through the primary winding 74 is controlled by the potential on the grid 4 of the trigger tube 1. A high-voltage pulse becomes thereupon momentarily transmitted through the transformer 36 to the spark-gap electrode 150, which affects ionization of the gas between the spark-gap elec-

trodes 104 and 106 and renders the spark gap conducting.

When the gap becomes conducting the voltage of the condenser 11 becomes impressed across the primary winding 113 of the transformer 114 in series with a small condenser 140. The condenser 140 may be of the order of 0.1 microfarad compared to 10 microfarads for the condenser 11. This prevents any appreciable portion of the energy in the condenser 11 from being dissipated in the series circuit comprising the condenser 11, the transformer, primary winding 113, the condenser 140, and the triggered spark gap. The voltage surge applied to the primary winding 113 of the transformer 114 produces a high voltage in the secondary winding 115. The voltages of both the primary and secondary windings 113 and 115 of the transformer 114 are in series circuit with the flashtube 18. The lamp 18 will break down and become conducting if the total applied voltage is sufficient in magnitude. The main-discharge condenser 11 will then discharge through the spark gap, the flash-lamp 18 and the secondary winding 115 of the transformer 114.

Since the impedance 23 is essentially in parallel with the flash lamp 18, its value should be relatively high compared to the impedance of the lamp 18 during the time that the condenser 11 is discharging into the flash lamp 18. On the other hand, the impedance 23 should not be too large, as this would tend to prolong the time required to recharge the condenser 11.

In the system of both Figs. 1 and 2, the three-electrode spark gap isolates the flashtube 18 from the high direct-current potentials of the condenser 11, except at the instant of flash. As these high-potential elements may be completely enclosed at some distance from the lamp 18, the operator may be fully protected from these high potentials, except at the moment of discharge. The enclosure, not shown, for these high-potential elements may be rendered sound-proof, in order to render the operation of the spark gap inaudible.

Further modifications will occur to persons skilled in the art, and all such are considered to fall within the spirit and scope of the invention, as defined in the appended claims.

What is claimed is:

1. An electric system having, in combination, a gaseous-discharge device, a condenser, means for charging the condenser, a saturable-core inductor, a spark gap, a discharge circuit for the condenser including the gaseous-discharge device, the inductor and the spark gap connected in series, and means for impressing a voltage upon the spark gap of magnitude sufficient to cause the spark gap to become conducting, thereby impressing a voltage upon the inductor such that, when added to the charge on the condenser, it will exceed the magnitude of the break-down voltage of the gaseous-discharge device, thereby to enable the condenser to discharge through the discharge circuit.

2. A flash-producing system having, in combination, a flash device, a condenser, means for charging the condenser, a saturable-core inductor, a spark gap, a discharge circuit for the condenser including the flash device, the inductor and the spark gap, and means for impressing a voltage upon the spark gap of magnitude sufficient to cause the spark gap to become conducting, thereby impressing a voltage upon the inductor such that, when added to the charge on the condenser, it will exceed the magnitude of the break-down voltage of the flash device, thereby to enable the condenser to discharge through the discharge circuit in order to produce a flash.

3. An electric system having, in combination, a gaseous-discharge device, a condenser, means for charging the condenser, a saturable-core transformer having a primary winding and a secondary winding, a spark gap, a discharge circuit for the condenser including the gaseous-discharge device, one of the windings of the transformer and the spark gap connected in series, and means for impressing a voltage upon the spark gap of magnitude sufficient to cause the spark gap to become conducting, thereby impressing a voltage upon the other winding to cause a voltage to appear on the said one winding of magnitude such that, when added to the charge on the condenser, it will exceed the magnitude of the break-down voltage of the gaseous-discharge device, thereby to enable the condenser to discharge through the discharge circuit.

4. A flash-producing system having, in combination, a flash device, a condenser, means for charging the condenser, a saturable-core transformer having a primary winding and a secondary winding, a spark gap, a discharge circuit for the condenser including the flash device, one of the windings of the transformer and the spark gap, and means for impressing a voltage upon the spark gap of magnitude sufficient to cause the spark gap to become conducting, thereby impressing a voltage upon the other winding to cause a voltage to appear on the said winding of magnitude such that, when added to the charge on the condenser, it will exceed the magnitude of the break-down voltage of the flash device, thereby to enable the condenser to discharge through the discharge circuit in order to produce a flash.

5. An electric system, having, in combination, a gaseous-discharge device, a condenser, means for charging the condenser, a saturable-core inductor, a three-electrode spark gap, a discharge circuit for the condenser including the gaseous-discharge device, the inductor and two of the electrodes of the spark gap, and means for impressing a voltage upon the third electrode of the spark gap of magnitude sufficient to cause the spark gap to become conducting, thereby impressing a voltage upon the inductor such that, when added to the charge on the condenser, it will exceed the magnitude of the break-down voltage of the gaseous-discharge device, thereby to enable the condenser to discharge through the discharge circuit.

6. An electric system having, in combination, a gaseous-discharge device, a condenser, means for charging the condenser, a saturable-core transformer, a three-electrode spark gap, a discharge circuit for the condenser including the gaseous-discharge device, the transformer and two of the electrodes of the spark gap, and means for impressing a voltage upon the third electrode of the spark gap of magnitude sufficient to cause the spark gap to become conducting, thereby impressing a voltage upon the inductor such that, when added to the charge on the condenser, it will exceed the magnitude of the break-down voltage of the gaseous-discharge device, thereby to enable the condenser to discharge through the discharge circuit.

7. An electric system having, in combination, a gaseous-discharge device having two electrodes, a condenser, means for charging the condenser, a saturable-core transformer having a primary winding and a secondary winding each having two ends, one end of one of the windings being connected to one end of the other winding, the other end of the said one winding being connected to one of the electrodes of the discharge device, the other end of the said other winding being connected to the other electrode of the discharge device, a three-electrode spark gap, a discharge circuit for the condenser including the gaseous-discharge device, one of the windings of the transformer and two of the electrodes of the spark gap, and means for impressing a voltage upon the third electrode of the spark gap of magnitude sufficient to cause the spark gap to become conducting, thereby impressing a voltage upon the inductor such that, when added to the charge on the condenser, it will exceed the magnitude of the break-down voltage of the gaseous-discharge device, thereby to enable the condenser to discharge through the discharge circuit.

8. An electric system having, in combination, a gaseous-discharge device, a condenser, means for charging the condenser, a saturable-core inductor, a three-electrode spark gap, a discharge circuit for the condenser including the gaseous-discharge device, the inductor and two of the electrodes of the spark gap, and means comprising a grid-controlled rectifier for impressing a voltage upon the third electrode of the spark gap of magnitude sufficient to cause the spark gap to become conducting, thereby impressing a voltage upon the inductor such that, when added to the charge on the condenser, it will exceed the magnitude of the break-down voltage on the gaseous-discharge device, thereby to enable the condenser to discharge through the discharge circuit.

9. A flash-producing system having, in combination, a gaseous-discharge flash device, a condenser, means for charging the condenser, a saturable-core inductor, a three-electrode spark gap, a discharge circuit for the condenser including the flash device, the inductor and two of the electrodes of the spark gap, and means comprising a grid-controlled rectifier for impressing a voltage upon the third electrode of the spark gap of magnitude sufficient to cause the spark gap to become conducting, thereby impressing a voltage upon the inductor such that, when added to the charge on the condenser, it will exceed the magnitude

of the break-down voltage of the flash device, thereby to enable the condenser to discharge through the discharge circuit in order to produce a flash.

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