Nov. 1, 1955 K. J. GERMESHAUSEN 2,722,629

ELECTRIC SYSTEM

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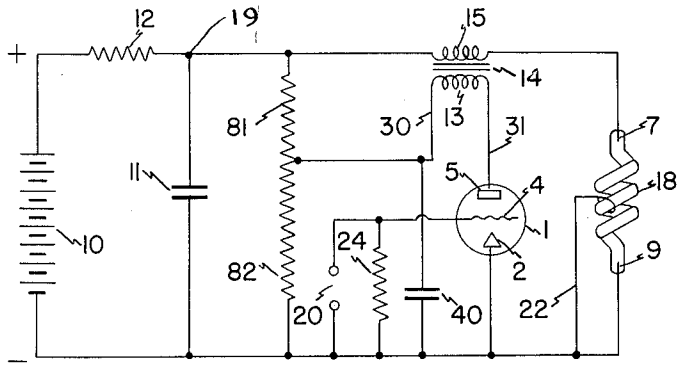


FIG. 1

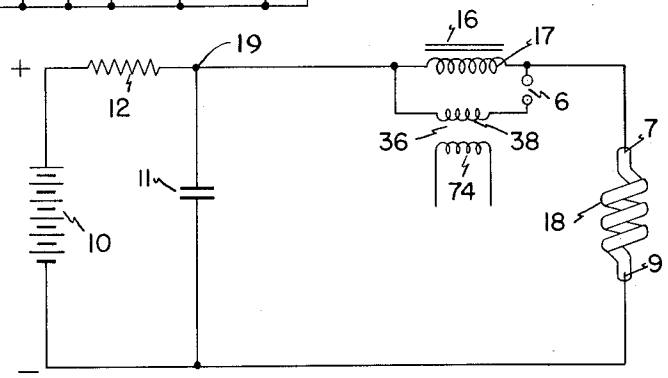


FIG. 2

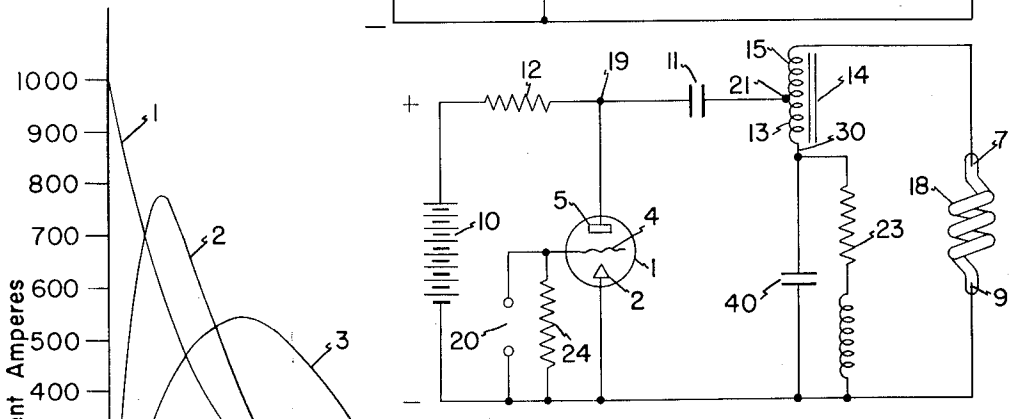


FIG. 4

FIG. 3

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ELECTRIC SYSTEM

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38 Claims. (Cl. 315—163)

The present invention relates to electric systems, and more particularly to methods and systems embodying gaseous-discharge devices. The invention has special reference to circuits of the above-described character in which a flash condenser is discharged through the gaseous medium of the 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 type 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 starting or control electrode, often in the form of an externally disposed high-voltage trigger wire. The necessity for employing the trigger wire introduces complexities and increases the size of the gaseous-discharge device, but proposals that have heretofore been made for eliminating this starting or control electrode have not been satisfactory.

An object of the present invention, therefore, is to provide a new and improved electric system, and a new and improved flash-producing system, of the above-described character embodying a two-electrode gaseous-discharge device. Certain features of the invention are not, however, restricted to two-electrode gaseous-discharge devices.

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

A further object is to provide a new and improved condenser-discharge circuit.

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

With the above ends in view, a feature of the invention resides in a series-triggering arrangement for producing the flash through the medium of a voltage provided by a saturable core inductance disposed in a specific part of the condenser-discharge circuit.

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; Fig. 2 is a similar view of a modification; Fig. 3 is a view of an explanatory diagram; and Fig. 4 is a view similar to Fig. 1 illustrating a modified arrangement employing a series transformer.

A main discharge flash condenser or capacitor 11, shown charged from a direct-current source, illustrated as a battery **10**, through a current-limiting 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 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**.

In Fig. 1, the secondary winding **15** of a triggering transformer **14** is shown series-connected in the condenser-discharge circuit. A high voltage pulse is designed to be impressed momentarily upon this secondary winding **15**, at a suitable time. This high-voltage pulse will become communicated to the condenser-discharge circuit, thereby, if of sufficient magnitude, initiating the discharge of the condenser **11** through the condenser-discharge circuit.

The momentary voltage pulse 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 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, 2,201,166 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 other 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 source 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 the triggering of the tube **1** will depend upon the design of the particular tube **1** employed.

The polarity of the voltage pulse impressed upon the secondary winding **15** is preferably in the same sense as the sense of the voltage across the condenser **11**. This polarity being therefore additive with respect to the charge on the condenser **11**, it will aid the voltage across this condenser **11**. This will reduce the magnitude of the voltage required to be supplied by the transformer **14** to fire the lamp **18**. The lamp **18** becomes momentarily rendered conducting by ionization when the voltage thus impressed upon the secondary winding **15**, added to the voltage of the condenser **11**, exceeds the breakdown voltage between the anode **7** and the cathode **9**. For a typical tube, this voltage may be on the order of twice the voltage at which the tube is designed to operate; say, 5,000 volts.

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 con-

verts a greater proportion of the energy in the condenser 11 into useful light.

A wire 22 from one end of the lamp 18, shown as the cathode end, wrapped around the outside of the glass envelope of the lamp 18, at an intermediate point thereof, will lower the impulse breakdown voltage of the tube 18, thus reducing the voltage pulse required from the transformer 14. No impedance additional to the impedance of the wire 22 is needed to prevent sustained arcing between the cathode 9 and this trigger electrode 22 over the exterior surface of the flashtube 18, if such arc is initiated by any cause.

Since the secondary winding 15 of the transformer 14 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 the 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 13 be reasonably high at the time that the triggering impulse is applied to the primary winding 13 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 13, which may be fairly long, shall not be too great compared to the impedance of this primary winding 13. The required low impedance of the secondary winding 15, at the time of the discharge of the condenser 11, and the required high impedance of the primary winding 13, at the time that the triggering impulse is applied to the primary winding 13, prior to the discharge of the condenser 11, may be attained by providing the transformer 14 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 15. It is because of the saturable character of the core of the transformer 14 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 15 of the transformer 14 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 flash-lamp 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 15 and the lamp 18 will depend on the relative proportions of the resistance, the inductance and the capacitance.

With a condenser voltage of 4,000, a lamp impedance of 4 ohms, and a secondary transformer winding 15 of zero-saturated impedance, the transient current will be represented by the curve 1 of Fig. 3. With the same 4,000 voltage value, and the same 4-ohm lamp impedance, but with an inductance of 40 microhenries for the secondary winding 15 of the transformer 14, the current will be represented by the curve 2. If, without any change in the voltage and the lamp impedance, the inductance be increased to 160 microhenries, the current will be represented by the curve 3.

It appears, from these curves, that the saturated inductance of the secondary winding 15 of the transformer 14 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 15 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 14. 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 14 may have a closed 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 15 of 50 turns and a primary winding 13 of 5 turns. When the iron core is saturated, the inductance of the primary winding 13 may be of the order of 0.20 microhenry, and that of the secondary winding 15 is of the order of 20 microhenries. The saturated inductance of 20 microhenries for the secondary winding 15 is well below the value 40 microhenries associated with the curve 2 of Fig. 3. 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 30 and 31.

The impedance across which the excess voltage to the lamp 18 is delivered need not be constituted, however, of the secondary winding 15 of the transformer 14. Other reactors may also be employed. The impedance may, for example, be in the form of a saturable inductor reactor 17 comprising, as illustrated in Fig. 2, an iron core 16. The unsaturated inductance of the inductance 17 may be 20 millihenries, and its saturated value may be 20 microhenries.

The voltage to trigger the tube 18 may be applied across the inductor 17 in any of many ways, so long as the rate of rise of the applied voltage is maintained high enough so that the unsaturated impedance of the inductor 17 shall be high compared to the impedance of the source supplying the voltage. According to the embodiment of the invention illustrated in Fig. 2, a high-ratio trigger transformer 36 of the spark-coil type is employed, the primary winding 74 and the secondary winding 38 of which are both of high impedance compared to the impedance of the transformer 14 of Fig. 1. The rate of rise of voltage across the secondary winding 38, therefore, is comparatively low and the impedance of the secondary winding 38 is high compared to the impedance of the inductor 17. A spark gap 6, however, in series with the secondary winding 38 and the inductor 17, prevents the inductor 17 from short-circuiting the transformer 36 until its secondary voltage has built up to the desired value. The spark gap 6 will then break down, impressing across the inductor 17 a high transient voltage in series with the condenser 11 and the lamp 18, and having a very high rate of rise. The magnitude of this high transient voltage is sufficient to trigger the lamp 18. The momentary currents required will be supplied by the distributed capacitance of the transformer 36. Energy may be supplied to the transformer 36 as described above in connection with Fig. 1.

According to the embodiment of the invention illustrated in Fig. 4, a saturated series transformer 14 is employed, as in the system of Fig. 1, but the main-discharge current of the condenser 11 passes through the trigger tube 1 as well as through the lamp 18. The anode 5 is connected to a terminal 19 between the current-limiting impedance 12 and one terminal of the condenser 11, and

the other terminal of the condenser **11** is connected to an intermediate point **21** of the inductor, one part of which, on one side of the point **21**, is designated by the numeral **13**, and the other part of which, on the other side of the point **21**, by the numeral **15**, to emphasize the similarity in function to the primary and secondary windings **13** and **15** of the transformer **14** of Fig. 1.

This circuit possesses the advantage that, because the trigger tube **1** is normally non-conducting, the flash tube **18** is isolated, at the point **21**, from the potential of the condenser **11**, except at the instant of flashing, thus presenting a safety feature that lessens the hazards to the operator. The isolation of the flash tube **18** from the condenser **11** becomes broken down when the trigger tube **1** is rendered conducting in response to a voltage impulse applied to the grid **21** through the terminals **20**.

In this circuit of Fig. 4, the main-discharge capacitor **11** is charged from the direct-current source **10**, not only through the current-limiting impedance **12**, but also through an impedance **23** in parallel or shunt with the condenser **40**. The impedance **23** is shown as embodying both resistance and inductance and is of impedance value high in relation to that of the lamp **18** when the latter is conductive in order that the capacitor **11** may discharge through the lamp **18** and not through the impedance **23**.

When it is desired to flash the lamp **18**, the tube **1** is triggered by means of a potential pulse applied to the terminals **20**, as in the system of Fig. 1. When the tube **1** is triggered, the voltage of the condenser **11** is applied across the primary winding **13** of the transformer **14**, in series with the small trip condenser **40** and the trigger tube **1**. The condenser **40** may be of the order of 0.1 microfarad, compared to 10 microfarads for the condenser **11**. The voltage surge applied to the primary winding **13** of the transformer **14** produces a high voltage in the secondary winding **15**. The voltages of both the primary and secondary windings **13** and **15** of the transformer **14** are thus in series circuit with the flash tube **18**. The lamp **18** will break down and become conducting if the series voltages of the primary and secondary windings **13** and **15** are of sufficient magnitude. The main discharge condenser **11** will then discharge through the tube **1**, the flash lamp **18** and the secondary winding **15** of the transformer **14**, in series.

In the systems of Figs. 1 and 2, the condenser **11** is charged to a voltage less than the break-down voltage of the flashtube **18**. This is not, however, true of the system of Fig. 4. In all three systems, nevertheless, the voltage impressed upon the saturable-core reactor **15** or **17** is of magnitude such that, when added to the charge upon the condenser **11**, it will exceed the magnitude of the break-down voltage of the flashtube **18**.

To handle the high-peak discharge currents, the tube **1** may be replaced by a triggered three-electrode spark gap, not shown.

In flash photography, the triggering voltage pulse may be applied to the terminals **20** at will, whenever it is desired to produce the exposure flash. For stroboscopic work, the triggering voltage pulse will be applied to the terminals **20** at selected intervals of time determined by the desired rate of flashing.

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 discharge circuit for the condenser including the gaseous-discharge device, an inductance having a saturable core series-connected in the discharge circuit, and means for impressing a voltage across the inductance to cause the condenser to discharge through the discharge circuit and the gaseous-discharge device.

2. A flash-producing system having, in combination, a flash device, a condenser, means for charging the condenser, an inductor having a saturable core, a discharge circuit for the condenser including the flash device and the inductor, and means for varying the voltage of the inductor to cause the condenser to discharge through the discharge circuit and the flash device to cause the flash device to produce a flash.

3. An electric system having, in combination, a gaseous-discharge device, a condenser, means for charging the condenser, a discharge circuit for the condenser including the gaseous-discharge device, a transformer having a saturable core series-connected in the discharge circuit, and means for impressing a voltage across the transformer to cause the condenser to discharge through the discharge circuit and the gaseous-discharge device.

4. A flash-producing system having, in combination, a flash device, a condenser, means for charging the condenser, a discharge circuit for the condenser including the flash device, a triggering transformer having a primary winding, a saturable core and a secondary winding connected to the discharge circuit, and means for exciting the primary winding to cause the condenser to discharge through the discharge circuit and the flash device to cause the flash device to produce a flash.

5. An electric system having, in combination, a gaseous-discharge device, a condenser, a source of energy for charging the condenser, a saturable inductor, a triggering device, a discharge circuit for the condenser including the gaseous-discharge device, the inductor and the triggering device connected in series, and means for triggering the triggering device to impress a voltage on the inductor, thereby to cause the condenser to discharge through the discharge circuit and the gaseous-discharge device.

6. A flash-producing system having, in combination, a flash device, a condenser, a source of energy for charging the condenser, an inductor having a saturable core, a triggering device, a discharge circuit for the condenser including the flash device, the inductor and the triggering device, and means for triggering the triggering device to impress a voltage on the inductor, thereby to cause the condenser to discharge through the discharge circuit and the flash device to cause the flash device to produce a flash.

7. An electric system having, in combination, a gaseous-discharge device, a condenser, means for charging the condenser, a transformer having primary and secondary windings, a discharge circuit for the condenser including the gaseous-discharge device and the secondary winding, and means for impressing a voltage upon the primary winding to cause the condenser to discharge through the discharge circuit, the transformer having a saturable core to reduce the effective impedance of the primary and the secondary windings at the time of the discharge of the condenser through the discharge circuit.

8. An electric system having, in combination, a gaseous-discharge device, a condenser, means for charging the condenser, a saturable inductor, a discharge circuit for the condenser including the gaseous-discharge device and the inductor, a transformer having a primary winding and a secondary winding, a spark gap, means for connecting the secondary winding and the spark gap across the inductor, and means for impressing a voltage upon the primary winding to cause the condenser to discharge through the discharge circuit.

9. An electric system having, in combination, a gaseous-discharge device, a condenser, means for charging the condenser, a saturable-core transformer, a trigger tube for triggering the transformer, a discharge circuit for the condenser including the gaseous-discharge device, the transformer and the trigger tube, and means for triggering the trigger tube to cause the condenser to discharge through the discharge circuit.

10. An electric system having, in combination, a gas-

eous-discharge device, a condenser, means for charging the condenser, a saturable-core transformer, a discharge circuit for the condenser including the gaseous-discharge device and the transformer, means for normally isolating the gaseous-discharge device from the condenser, and means for breaking down the isolation of the gaseous-discharge device from the condenser to impress a voltage upon the transformer, thereby to cause the condenser to discharge through the discharge circuit.

11. An electric system having, in combination, a gaseous-discharge device, a condenser, means for charging the condenser, a saturable-core transformer, a discharge circuit for the condenser including the gaseous-discharge device and the transformer, a normally non-conducting gaseous-discharge tube for normally isolating the gaseous-discharge device from the condenser, and means for rendering the gaseous-discharge tube conducting in order to break down the isolation of the gaseous-discharge device from the condenser, thereby to impress a voltage upon the transformer for causing the condenser to discharge through the discharge circuit.

12. A flash-producing system having, in combination, a gaseous-discharge flash device, a condenser, means for charging the condenser, a discharge circuit for the condenser including the gaseous-discharge flash device, a saturable core inductance series connected in the discharge circuit, and means for impressing a voltage pulse at will across the inductance to cause the condenser to discharge through the discharge circuit and the gaseous-discharge flash device in order to produce a flash.

13. A stroboscope having, in combination, a gaseous-discharge flash device, a condenser, means for charging the condenser, a discharge circuit for the condenser including the gaseous-discharge flash device, a saturable core inductance series connected in the discharge circuit, and means for impressing voltage pulses at selected intervals across the inductance to cause the condenser to discharge at the selected intervals through the discharge circuit and the gaseous-discharge flash device in order to produce flashes at the selected intervals.

14. In combination, a condenser, means for charging said condenser, a space discharge tube possessing an anode, cathode and triggering electrode, means connecting said triggering electrode to said anode, a winding possessing a saturable core, means connecting said discharge tube from cathode to anode across said condenser in series with said winding, and means for inducing a voltage pulse in said winding in additive polarity with respect to the charge on said condenser for triggering said discharge tube.

15. In combination, a condenser, means for charging said condenser, a space discharge tube possessing electrodes including an anode and a cathode, a winding possessing a saturable core, means connecting said discharge tube from cathode to anode across said condenser in series with said winding, and means for inducing a voltage pulse in said winding in additive polarity with respect to the charge on said condenser for triggering said discharge tube.

16. In combination, a condenser, means for charging said condenser, a saturable core transformer possessing a primary and a secondary winding, first circuit means including a switch adapted to cause a short current pulse through the primary of said transformer upon actuation of said switch, a space discharge tube possessing electrodes including an anode and a cathode, second circuit means adapted to connect said discharge tube across said condenser and the secondary winding of said transformer in series thereby utilizing the transient voltage in said secondary winding caused by a short current pulse in said primary to trigger said space discharge tube and allowing discharge of said condenser through said discharge tube.

17. In combination, D. C. energy storing means, means for supplying energy intermittently to said storing means, a saturable core transformer having at least two windings, normally open switching means, circuit means connecting one winding of said transformer and said switching means in series across said energy storing means, means for actuating said switching means to closed condition, automatic resetting means responsive to integrated current flow through said switching means for returning said switching means to normal open condition, a cold cathode space discharge tube possessing electrodes including a cathode and an anode, and means connecting a second winding of said transformer and said space discharge tube in series across said energy storing means.

18. In combination, an electrical condenser, means for intermittently charging said condenser, a saturable core transformer possessing at least two windings, a thermionic gaseous discharge tube possessing a cathode, anode, and control grid, means connecting said condenser, a winding of said transformer and said gaseous discharge tube in series relationship, means controlling the grid of said gaseous discharge tube, automatic resetting means responsive to the integrated current flow through said gaseous discharge tube for causing said tube to become non-conducting, a cold cathode space discharge tube possessing electrodes including a cathode and an anode, and means connecting a second winding of said transformer and said cold cathode discharge tube in series across said condenser.

19. An energizing circuit for a flashtube comprising a D. C. voltage source connected to sustain a flow of current through the flashtube, a saturable core transformer having its secondary series connected in the circuit between the flashtube and said source, and means to apply a voltage impulse to the primary of said transformer of proper polarity to induce a voltage in the secondary having a polarity additive to that of said source.

20. An energizing circuit for a flashtube comprising a capacitor connected between the cathode and anode of the flashtube, a saturable core transformer having its secondary series connected in the circuit between the flashtube and said capacitor, means for charging said capacitor to a D. C. voltage sufficient to sustain but not to initiate current through the flashtube, and means to apply a voltage impulse to the primary of said transformer of proper polarity to induce a voltage in the secondary having a polarity additive to that of the capacitor voltage.

21. An energizing circuit for a flashtube comprising a capacitor, circuit means for connecting said capacitor between the cathode and anode of the flashtube, a saturable core transformer having its secondary series connected in the circuit between the flashtube and said capacitor, means for charging said capacitor to a D. C. voltage sufficient to sustain but not to initiate current through the flashtube, and switching means adapted upon actuation to suddenly connect the primary of said transformer across said capacitor, the relative polarities of the transformer primary and secondary being such that upon actuation of the switching means a voltage is induced in the secondary having a polarity additive to that of the capacitor voltage.

22. An energizing circuit for a flashtube comprising a capacitor connected between the cathode and anode of the flashtube, a saturable core transformer having its secondary series connected in the circuit between the flashtube anode and said capacitor, means for charging said capacitor to a D. C. voltage sufficient to sustain but not to initiate current through the flashtube, and switching means adapted upon actuation to suddenly connect the primary of said transformer across said capacitor, the relative polarities of the transformer primary and secondary being such that upon actuation of the switching means a voltage is induced in the secondary having a polarity additive to that of the capacitor voltage.

23. An energizing circuit for a flashtube comprising a capacitor connected between the cathode and anode of the flashtube, a saturable core transformer having its

secondary series connected in the circuit between the flashtube and said capacitor, means for charging said capacitor to a D. C. voltage sufficient to sustain but not to initiate current through the flashtube, a normally non-conducting grid-controlled discharge tube connected in series with the primary of said transformer across said capacitor, and means to apply a triggering voltage to the grid of said discharge tube to make such tube conductive, the relative polarities of the transformer primary and secondary being such that upon the discharge tube becoming conductive a voltage is induced in the secondary having a polarity additive to that of the capacitor voltage.

24. In a flashtube energizing circuit, apparatus for producing a triggering impulse comprising a first capacitor, means for charging said first capacitor, a transformer, a second capacitor, a normally non-conductive grid-controlled discharge tube, said first capacitor, the primary of said transformer, said second capacitor, and said discharge tube being series connected in a closed circuit loop, a resistor connected in parallel with said second capacitor, and means to apply a triggering voltage to the grid of said discharge tube to make such tube conductive.

25. An energizing circuit for a flashtube comprising a first capacitor connected between the cathode and anode of the flashtube, a saturable core transformer having its secondary series connected in the circuit between the flashtube and said capacitor, means for charging said first capacitor to a D. C. voltage sufficient to sustain but not to initiate current through the flashtube, a second capacitor, a normally non-conductive grid-controlled discharge tube having two principal electrodes, said second capacitor and the primary of said transformer being connected in series in the order named between one of the principal electrodes of said discharge tube and one plate of said first capacitor, the other plate of said first capacitor being connected to the other principal electrode of said discharge tube, a resistor connected in parallel with said second capacitor, and means to apply a triggering voltage to the grid of said discharge tube to make such tube conductive, the relative polarities of the transformer primary and secondary being such that upon the discharge tube becoming conductive a voltage is induced in the secondary having a polarity additive to that of the first capacitor voltage.

26. An electric circuit comprising a saturable core inductance device and a switch connected in series, means for applying a voltage across said series-connected inductance device and switch in order to impress an impulse voltage across said inductance device when said switch is closed, a gaseous discharge device having electrodes including a pair of main electrodes, means for applying a voltage between said pair of main electrodes, and means responsive to said impulse voltage for rendering said discharge device conductive.

27. An electric circuit comprising a saturable core inductance device and a first gaseous discharge device connected in series, means for applying a unidirectional voltage across said series-connected inductance device and first discharge device, means for rendering said first discharge device conductive to impress an impulse voltage across said inductance device, a second gaseous discharge device having a pair of main electrodes, means for applying a unidirectional voltage across said pair of main electrodes, and means responsive to said impulse voltage to render said discharge device conductive.

28. An electric circuit comprising a saturable core inductance device, a first gaseous discharge device, an energy storage means, circuit means for connecting said inductance device and said first discharge device in series across said energy storage means, means for charging said energy storage means to a D. C. voltage sufficient to sustain but not to initiate current through said first discharge device, means for rendering said first discharge device conductive to apply an impulse voltage across said inductance device, a second gaseous discharge device having a pair of main electrodes, means for applying a voltage across said pair of main electrodes, and means responsive to said impulse voltage for rendering said second discharge device conductive.

29. In a flashtube circuit, a triggering circuit comprising a saturable core inductance device and a switch connected in series, means for applying a unidirectional voltage across said series-connected inductance device and said switch in order to impress an impulse voltage across said inductance device upon the closing of said switch, and means responsive to said impulse voltage for rendering said flashtube conductive.

30. An energizing circuit for a plurality of gaseous discharge devices each having a pair of main electrodes which comprises a saturable core inductance device, a circuit means for connecting said inductance device and the main electrode of one of said gaseous discharge devices in series, means for applying a unidirectional voltage across said series-connected inductance device and first discharge device, means for rendering said one of said discharge devices conductive to apply an impulse voltage across said inductance device, and means responsive to said impulse voltage for rendering another of said discharge devices conductive when its main electrodes are connected to a voltage source.

31. An energizing circuit for a flashtube comprising a capacitor, a saturable core inductance device connecting one terminal of said capacitor to the anode of said flashtube, a gaseous discharge device, said discharge device being connected to said capacitor through said inductance device, means to trigger said discharge device to cause a pulse of voltage in said inductance device, said flashtube being arranged for triggering in response to such voltage pulses, said inductance device core being saturated by the induction current of said flashtube and discharge device whereby substantially the full voltage of said capacitor is applied to said flashtube to maintain conduction therein.

32. In combination, an energy storage means, means for charging said storage means, a saturable core inductance device, a gaseous discharge device, circuit means for connecting said inductance device and said first discharge device in series across said energy storage means, means for rendering said first discharge device conductive to impress an impulse voltage across said inductance device, a second gaseous discharge device connected across said energy storage means in series with said inductance device, and means responsive to said impulse voltage for rendering said second discharge device conductive.

33. In combination, a plurality of gaseous discharge devices, a direct current voltage source connected to said discharge devices, a saturable core inductance device connected in series between said discharge devices and said voltage source, means for rendering one of said discharge devices conductive to suddenly apply a voltage across said inductance device, and means responsive to said sudden voltage application to initiate current flow through another of said discharge devices, at least one of said discharge devices being arranged to emit light upon the passage of current therethrough.

34. An energizing circuit for a plurality of gaseous discharge devices comprising an energy storage means, means for charging said storage means, a saturable core inductance device, means for connecting said inductance device and one of said discharge devices in series across said energy storage means, means for rendering said one of said discharge devices conductive to switch an impulse voltage across said inductance device, means for connecting said inductance device and another of said discharge devices in series across said energy storage means, and means responsive to said impulse voltage for rendering said another of said discharge devices conductive, at

least one of said discharge devices being arranged to emit light upon the passage of current therethrough.

35. A flashtube energizing circuit comprising a first gaseous discharge device, a capacitor, means for charging said capacitor, said capacitor being connected to sustain a flow of current through said first discharge device when said device is rendered conductive, a saturable core inductance device serially connected between said first discharge device and said capacitor, means for triggering said first discharge device for suddenly impressing at least part of the voltage of said capacitor across said inductance device, and means responsive to said impressing of said voltage to trigger a second gaseous discharge device, at least one of said discharge devices being arranged to emit light upon the passage of current therethrough.

36. An energizing circuit for a flashtube comprising a unidirectional voltage source connected to sustain a flow of current through the flashtube, a saturable core inductance device serially connected between said flashtube and said source, a gaseous discharge device, said discharge device being connected to said voltage source through said inductance device, means for rendering said discharge device conductive to establish a sudden change of voltage across said inductance device before saturation thereof, means for rendering said flashtube conductive in response to said sudden change of voltage, said inductance device being saturated by the conduction current of said flashtube and said discharge device therethrough whereby substantially the full voltage of said source is applied to said discharge device and said flashtube.

37. In combination, an energy storing means, means for supplying energy to said storing means, a saturable core transformer having at least two windings, a first gaseous discharge device, circuit means connecting one winding of said transformer and said first gaseous discharge device in series across said energy storing means, a second gaseous discharge device, circuit means connecting a second winding of said transformer and said second discharge device in series across said energy storing means, and means for rendering said first gaseous discharge device conductive to thereby apply a voltage impulse to the primary winding of said transformer of proper polarity to induce a voltage in the secondary winding having a polarity additive to said source.

38. Apparatus for producing light flashes comprising an arc discharge lamp containing an ionizable gas, a condenser having one terminal connected to a terminal of said lamp, a switch having two terminals connected respectively to said condenser and said lamp and furnishing a low impedance path for discharging the condenser through the lamp, a direct-current-conductive shunt in parallel with said lamp for furnishing a charging path for said condenser when said lamp is non-conducting, said shunt having an impedance that is high in relation to that of the lamp when the latter is conductive, and a direct-current source having a current-limiting resistor and connected to the terminals of said switch for charging said condenser when said switch is open.

References Cited in the file of this patent

UNITED STATES PATENTS

1,927,425	Van der Mark	Sept. 19, 1933
2,043,484	Miller	June 9, 1936
2,068,596	Cox	Jan. 19, 1937
2,091,953	Bequemont	Sept. 7, 1937
2,096,865	Swart	Oct. 26, 1937
2,142,837	Edwards	Jan. 3, 1939
2,178,423	Inman	Oct. 31, 1939
2,236,195	McKesson	Mar. 25, 1941
2,269,338	Edgerton	Jan. 6, 1942
2,331,771	Germeshausen et al.	Oct. 12, 1943
2,375,130	Perrin	May 1, 1945
2,385,397	Blackburn	Sept. 25, 1945
2,391,611	Back	Dec. 25, 1945
2,411,898	Schelleng	Dec. 3, 1946
2,416,718	Shockley	Mar. 4, 1947
2,431,952	Maxwell	Dec. 2, 1947
2,509,005	Lord	May 23, 1950
2,517,031	Rochester	Aug. 1, 1950

FOREIGN PATENTS

868,105	France	Sept. 15, 1941