July 24, 1956 K. J. GERMESHAUSEN 2,756,365

ELECTRIC-DISCHARGE SYSTEM

Filed Jan. 26, 1955 2 Sheets-Sheet 1

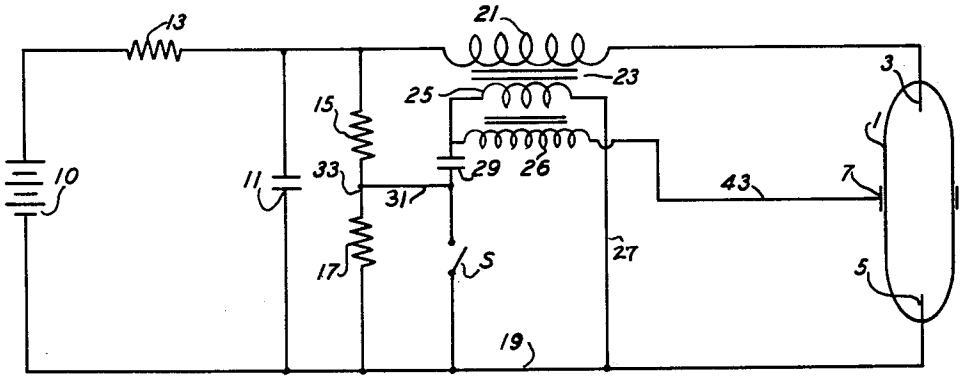


Fig. 2

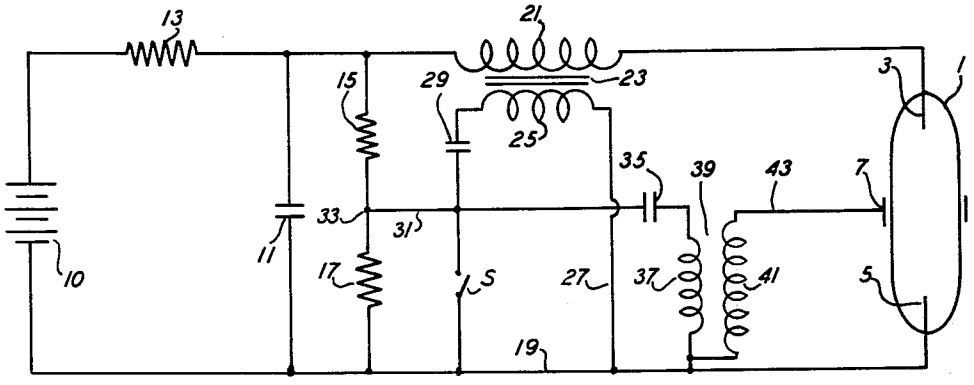


Fig. 1

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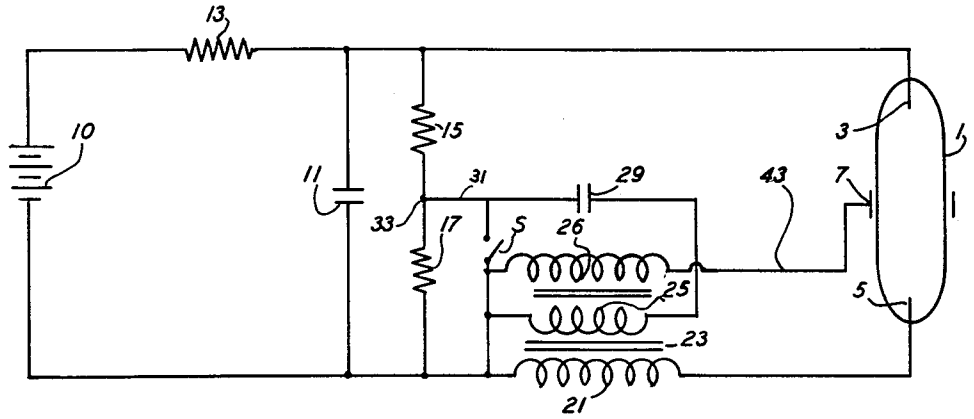


Fig 3

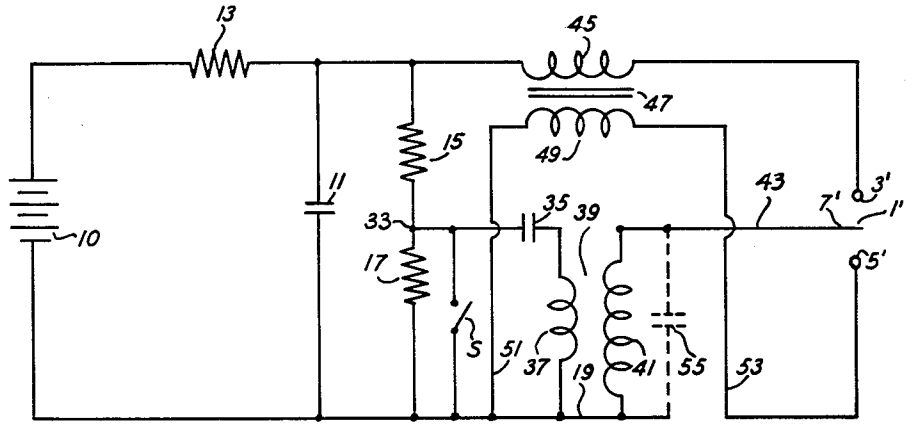


Fig. 4

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2,756,365

ELECTRIC-DISCHARGE SYSTEM

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Application January 26, 1955, Serial No. 484,220

13 Claims. (Cl. 315—234)

The present invention relates to electric-discharge systems, and, though it has application in fields of more general usefulness, it is particularly adapted for systems in which a flash condenser or capacitor is discharged through the gaseous medium of a gaseous-discharge device for such purposes as the production of a single flash of light or a repetition of flashes, as in flash photography, stroboscopic work and the like.

In my copending application, Serial No. 679,983, filed June 28, 1946, and entitled Electric System, and which matured on November 1, 1955 as United States Letters Patent No. 2,722,629, there is described a new and improved condenser charging-and-discharging apparatus that enables the use of relatively small two-electrode flashtubes in place of larger and more complex three-electrode flashtubes. Through the use of such two-electrode tubes, the flash-producing circuit is simplified, the size of the apparatus is reduced, and operation with low-voltage condensers and relatively small power supplies is possible. There are occasions, however, where it is desired to utilize the advantages of such low-voltage condensers and such small-size equipment, but with three-electrode tubes, and, in particular, with such tubes that can dissipate large amounts of energy. The present invention, accordingly, enables the use of three-electrode tubes with the same and even smaller low-voltage sources, flash condensers and other equipment that operate the two-electrode tubes, thus retaining the advantages of the circuits of the said copending application and patent, but supplemented with the further advantages of three-electrode tubes that normally require much larger condensers, power supplies and related equipment.

An object of the present invention, therefore, is to provide a new and improved electric system embodying a three-electrode gaseous discharge device that is adapted to operate with low voltages that are of themselves far too small normally to operate such three-electrode tubes.

Another object is to provide a new and improved electric system of the above-described character that, though employing a three-electrode electric-discharge device, is adapted to utilize series triggering arrangements of the type designed for two-electrode flash devices, as disclosed in the said copending application and patent. In summary, this result is achieved through the use of a series triggering arrangement wherein a low-voltage source is utilized in combination with a series voltage-adding mechanism which is rendered operative simultaneously with the application of a triggering impulse to the trigger electrode of a three-electrode tube.

A further object of the present invention is to provide a new and improved electric system embodying a three-electrode discharge device wherein the triggering electrode discharge is employed to produce a sharply rising high-frequency impulse for simultaneous series triggering.

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, Fig. 1 of which is a diagrammatic view of circuits and apparatus arranged and constructed in accordance with a preferred embodiment of the present invention;

Figs. 2 and 3 are similar views of modifications; and

Fig. 4 is a similar view of still a further modification, particularly adapted for use with spark-discharge devices.

Referring to Fig. 1, the three-electrode gaseous-discharge tube is shown at **1**, provided with a pair of principal electrodes **3** and **5** and a trigger or control electrode **7**, which may be either internal or external to the tube **1**. The tube, for example, may be of the type described in my Letters Patent No. 2,492,142, issued December 27, 1949, or of the type disclosed in Letters Patent No. 2,478,901 issued August 16, 1949 to Harold E. Edgerton, or of any other type, embodying any desired shape, configuration, type of electrodes or gases. A main discharge or flash condenser or capacitor **11** stores energy by charging from a direct-current source **10**, illustrated as a battery, through a current-limiting-charging impedance **13**. A bleeder network **15, 17** is connected in parallel with capacitor **11**. The lower electrode of this capacitor **11** is shown connected by conductor **19** to the lower or cathode principal electrode **5** of the gaseous-discharge flash tube **1**. The upper electrode of the capacitor **11** is shown connected in series with a secondary inductance winding **21** of a preferably saturable transformer **23**, to the upper or anode electrode **3** of the gaseous-discharge flashtube **1**. The primary winding **25** of the transformer **23** is connected on one side by a conductor **27** to the conductor **19**, and on the other side to a condenser **29**. The condenser **29** is connected by a conductor **31** to an intermediate terminal **33** of the bleeder network **15, 17**. The condenser **29** is thus charged in the circuit traceable from the intermediate terminal **33** of the bleeder network **15, 17**, through the condenser **29**, the primary winding **25**, and the conductors **27** and **19**, to the lower terminal of the bleeder resistor **17**. Also connected by the conductor **31** to the intermediate terminal **33** of the bleeder network **15, 17** is a further condenser **35**, which is similarly charged through the primary winding **37** of a high-voltage trigger transformer **39**. The upper terminal of the secondary winding **41** of the trigger transformer **39** is connected by the conductor **43** to the trigger or control electrode **7** of the three-electrode gaseous-discharge device **1**. The lower terminals of the primary winding **37** and the secondary winding **41** of the trigger transformer **39** are shown connected together to the conductor **19**.

A trigger switch S may be utilized to initiate the triggering of the tube **1**. The mechanical trigger switch S may be replaced by an electronic trigger circuit or any other impulse-producing device, if desired, as described, for example, in the said Letters Patent. Upon the closing of the switch S, the condenser **29** and the condenser **35** each becomes substantially simultaneously discharged. The condenser **29** discharges through the switch S and the primary winding **25** of the normally ineffective transformer **23**, thereby rendering the transformer **23** effective to induce a preferably stepped-up voltage in the secondary winding **21** thereof. Simultaneously, the condenser **35** discharges through the switch S and the primary winding **37** of the trigger transformer **39** to produce a trigger impulse in the secondary winding **41** that is thus applied to the trigger electrode **7**.

The application of the trigger pulse from the secondary winding **41** to the trigger electrode **7** of the gaseous-discharge tube **1** commences partial ionization of the gas in the tube **1**. There is simultaneously induced, however, in the secondary winding **21**, a voltage that is added in series with and in the same polarity as the voltage stored in the capacitor **11**, to produce a discharge between

the principal electrodes 3 and 5 of the gaseous-discharge tube 1. Since the tube 1 is triggered at the same time that this voltage in the secondary winding 21 is developed, much smaller voltages are required in the secondary winding 21 than would be the case if the trigger voltage were not applied to the tube 1. There is a tendency, moreover, as later more fully discussed in connection with the embodiment of Fig. 4, for the energy discharging from the trigger electrode 7 to increase the principal-electrode voltage differential, thereby to assist in the firing of the tube 1. The saturable transformer 23 may therefore even be of a much simpler construction and of less sizeable voltage rating than that required for operation of the two-electrode flashtubes described in the said copending application and patent. It is easier, therefore, to maintain the secondary winding 21 of such a lower-rated transformer 23 at low impedance, thus to provide for the maximum transfer of energy in the discharge circuit comprising the capacitor 11, the winding 21 and the principal electrodes 3 and 5 of the tube 1. The design of the saturable transformer 23 is therefore considerably simplified over that required for use with the two-electrode tube. The series voltage to be added to the voltage of the capacitor 11 does not, indeed, need to be as large as the voltage required in two-electrode flashtube circuits in view of the simultaneous breaking-down or partial ionization of the tube 1 by the application of the trigger pulse to the trigger electrode 7. This lower-voltage operation eases up on the rather strict requirements of the circuits of the said copending application as to the low impedance in the switch S and the inductance of the trigger circuit.

The three-cathode gaseous-discharge device 1 may therefore be operated with a relatively low-voltage energy-storage capacitor 11 through the expedient of the triggering of the three electrode tube 1 with the simultaneous application of voltage in series with the voltage of the capacitor 11 by means of the action of the saturable transformer 23. One may therefore employ the three-electrode tube 1 in order to take advantage of its ability to handle large amounts of energy in the discharge, and yet may operate the tube with the same low-voltage capacitor 11 that could normally be used with only the two-electrode tubes, and with a much lower-voltage saturable transformer 23 than is required for two-electrode-tube operation.

In the modification of Fig. 2, the condenser 35 and the separate trigger transformer 39 are not employed. The condenser 29, however, is utilized not only to energize the triggering of the trigger electrode 7 of the gaseous-discharge device 1, but also to produce the series voltage that is to be added to the capacitor 11 in the discharge circuit. Thus, when the switch S is closed, the condenser 29 discharges through the primary winding 25 of the somewhat modified saturable transformer 23. Upon the core of this transformer 23 may be wound a further high-voltage high-impedance secondary winding 26 cooperating with the transformer 23 and which serves the function of the trigger transformer 39 in the system of Fig. 1 and is connected between the condenser 29 and the trigger electrode 7. When the switch S is closed, therefore, the condenser 29 discharges through the primary winding 25, rendering the transformer 23 effective to induce simultaneously series voltage in the secondary winding 21 to add to the voltage of the capacitor 11 between the principal electrodes 3 and 5, and a trigger voltage impulse in the further secondary winding 26 to trigger the trigger electrode 7.

While the transformer 23 is shown in Figs. 1 and 2 in series connection between the upper electrode of the flash capacitor 11 and the anode 3 of the gaseous-discharge tube 1, it could equally well be placed in the connection to the cathode principal electrode 5. In Fig. 3, therefore, for purposes of illustration, the secondary winding 21 of the transformer 23 of the circuit of Fig. 2 is shown connected between the lower electrode of the capacitor 11

and the cathode principal electrode 5 of the flashtube 1.

The invention is by no means restricted, however, to the gaseous electric-discharge tubes of the character before described. Other electric-discharge devices may similarly be employed such as, for example, spark gaps of the type disclosed in Letters Patent No. 2,478,906, issued on the said August 16, 1949 to the said Harold E. Edgerton.

In Fig. 4, a circuit particularly adapted for use with spark gaps is illustrated, though this circuit is also useful with flask tubes. Where a spark gap is employed instead of a gaseous-discharge tube, it is necessary to the attainment of high efficiency that the gas pressure be relatively high; say, in excess of about 1 atmosphere. Even with such high pressure, however, and even though small gap spacings of the order of from about three-eighths to about one-half of an inch are employed, spark gaps have been found not to operate consistently at low voltages. It is usually necessary, therefore, to apply voltages in excess of about fifteen hundred volts to obtain satisfactory spark-gap operation. Through the techniques of the present invention, however, low voltages may be utilized reliably to operate spark gaps.

The principal electrode 3′ of the spark gap 1′ is shown connected through the secondary winding 45 of a saturable transformer 47 to the upper electrode of the capacitor 11. The lower electrode of the capacitor 11 is connected by a conductor 51 through the primary winding 49 of the saturable transformer 47, and by a conductor 53 to the cathode principal electrode 5′ of the spark gap 1′. The trigger electrode 7′ is connected by conductor 43 to the upper terminal of the secondary trigger winding 41 of the trigger transformer 39. The lower terminal of the secondary winding 41 is connected to the conductor 19. The windings 45 and 49 may, if desired, be separate inductors.

Upon the application of the trigger impulse to the primary winding 37 of the trigger transformer 39, effected by the closing of the switch S, a high-voltage trigger impulse is developed across the secondary winding 41. The high voltage developed across the secondary winding 41 applies a breakdown potential between, say, the trigger electrode 7′ and the lower principal electrode 5′. The resulting short-circuit between the electrodes 7′ and 5′ results in the application of the high trigger voltage to the primary winding 49 of the saturable transformer 47 in the circuit traceable from the upper terminal of the winding 41, by conductor 43 to the trigger electrode 7′ and the cathode 5′, thence by conductor 53 through the primary winding 49, and by conductor 51 to the lower terminal of the secondary winding 41.

There is a limited time in which one can apply such a high voltage to a saturable transformer winding before the transformer saturates. If, for example, a 5000-volt impulse is to be applied to the winding 49 from the trigger transformer 39, and the saturable transformer 47 saturates in one microsecond, then the voltage must be fully applied to the transformer 47 in substantially one microsecond. The circuit of Fig. 4 effects this automatically, since the distributed capacitance 55 of the trigger transformer secondary winding 41 tends to maintain the high voltage developed in the secondary winding 41. There is thus almost instantaneously applied to the primary winding 49 of the saturable transformer 47 the high frequency impulse from the trigger transformer secondary winding 41, as before described. The result is that the principal electrode 5′ assumes the potential of the voltage developed in the trigger transformer secondary winding 41, thereby lowering the voltage of the principal electrode 5′ with respect to the other anode principal electrode 3′ of the spark gap 1′ by at least an amount equal to the voltage developed across the secondary winding 41. If, for example, the voltage in the trigger transformer secondary winding 41 is 5000 volts, then the electrode 5′ instantaneously be-

comes 5000 volts negative with respect to the electrode 3'. The secondary winding 45 of the saturable transformer 47, however, is so wound that the voltage induced in it adds in the same sense with the relatively low voltage of the condenser 11. The principal electrodes 3' and 5' thus differ in potential not only by the high voltage developed across the trigger transformer secondary winding 41, but, also, by the additional voltage of the capacitor 11 and the voltage developed in the secondary winding 45 of the saturable transformer 47 as it is rendered effective to add voltage in series with the voltage of the capacitor 11. A very large voltage differential between the electrodes 3' and 5' is thus instantaneously built up, causing the spark gap to flash over and to discharge the voltage of the capacitor 11 and the voltage in the secondary winding 45 through the spark gap 1'.

Through the expedient of similar saturable windings 49 and 45, it makes no difference in the operation of the circuit whether the trigger electrode 7' initially arcs over to the principal electrode 3' or to the principal electrode 5' to start the above-described sequence. In both cases, the trigger impulse applied to the secondary winding 41 is almost simultaneously applied to the saturable transformer 47, producing a large over-voltage between the electrodes 3' and 5' in order to permit the discharge therebetween. This is reliably accomplished, moreover, even though a voltage is employed on the capacitor 11 that is relatively low, say of the order of 450 or 500 volts. A further feature of the circuit of Fig. 4 resides in the fact that it is inherently adapted for the use of low currents in the trigger circuit of the primary winding 37 of the trigger transformer 39.

Further modifications will occur to those 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 flash-producing system having, in combination, an electric flash device having a pair of principal electrodes and a trigger electrode, energy storage means, a charging circuit for storing voltage in the energy storage means, a discharge circuit for the energy storage means connected to the principal electrodes and including normally ineffective means for adding voltage, when effective, in the discharge circuit in series with and in the same polarity as the voltage of the energy storage means, and means for supplying a trigger impulse to the trigger electrode and substantially simultaneously rendering the normally ineffective means effective, thereby to enable the energy storage means to discharge through the discharge circuit in order to produce a flash between the principal electrodes of the flash device.

2. An electric flash-producing system having, in combination, an electric flash device having a pair of principal electrodes and a trigger electrode, a condenser, means for charging the condenser, a discharge circuit for the condenser connected to the principal electrodes and including an inductor for adding voltage, when voltage is induced therein, in the discharge circuit in series with and in the same polarity as the voltage of the condenser, and means for supplying a trigger impulse to the trigger electrode and substantially simultaneously inducing a voltage in the inductor, thereby to enable the condenser to discharge through the discharge circuit in order to produce a flash between the principal electrodes of the flash device.

3. An electric flash-producing system having, in combination, an electric flash device having a pair of principal electrodes and a trigger electrode, a condenser, means for charging the condenser, a discharge circuit for the condenser connected to the principal electrodes and including a saturable-core inductor for adding voltage, when voltage is induced therein, in the discharge circuit in series with and in the same polarity as the voltage of the condenser, and means for supplying a trigger impulse to the trigger electrode and substantially simultaneously inducing a voltage in the inductor, thereby to enable the condenser to discharge through the discharge circuit in order to produce a flash between the principal electrodes of the flash device.

4. An electric flash-producing system having, in combination, an electric flash device having a pair of principal electrodes and a trigger electrode, a condenser, means for charging the condenser, a transformer having a primary winding and a secondary winding, a discharge circuit for the condenser connected to the principal electrodes and including the secondary winding disposed to add voltage in the discharge circuit in series with and in the same polarity as the voltage of the condenser, and means for supplying a trigger impulse to the trigger electrode and substantially simultaneously an impulse to the primary winding, thereby to enable the condenser to discharge through the discharge circuit in order to produce a flash between the principal electrodes of the flash device.

5. An electric flash-producing system having, in combination, an electric flash device having a pair of principal electrodes and a trigger electrode, a condenser, means for charging the condenser, a transformer having a primary winding, a saturable core and a secondary winding, a discharge circuit for the condenser connected to the principal electrodes and including the secondary winding disposed to add voltage in the discharge circuit in series with and in the same polarity as the voltage of the condenser, and means for supplying a trigger impulse to the trigger electrode and substantially simultaneously an impulse to the primary winding, thereby to enable the condenser to discharge through the discharge circuit in order to produce a flash between the principal electrodes of the flash device.

6. An electric flash-producing system having, in combination, an electric flash device having a pair of principal electrodes and a trigger electrode, condenser means, means for charging the condenser means, a discharge circuit for the condenser means connected to the principal electrodes and including normally ineffective means for adding voltage, when effective, in the discharge circuit in series with and in the same polarity as the voltage of the condenser means, a bleeder network connected with the condenser-charging means, further condenser means, means for charging the further condenser means from the bleeder network, means for discharging the further condenser means, and means controlled by the last-named means for supplying a trigger impulse to the trigger electrode and substantially simultaneously rendering the normally ineffective means effective, thereby to enable the first-named condenser means to discharge through the discharge circuit thereof in order to produce a flash between the principal electrodes of the flash device.

7. An electric flash-producing system having, in combination, an electric flash device having a pair of principal electrodes and a trigger electrode, a trigger winding connected to the trigger electrode, condenser means, means for charging the condenser means, a transformer having a primary winding, a saturable core and a secondary winding, a discharge circuit for the condenser means connected to the principal electrodes and including the secondary winding disposed to add voltage in the discharge circuit in series with and in the same polarity as the voltage of the condenser means, a bleeder network connected with the condenser-charging means, further condenser means, means for charging the further condenser means from the bleeder network, means for discharging the further condenser means, and means controlled by the last-named means for supplying an impulse to the trigger winding and substantially simultaneously an impulse to the primary winding to enable

the first-named condenser means to discharge through the discharge circuit thereof in order to produce a flash between the principal electrodes of the flash device.

8. An electric flash-producing system as claimed in claim 7 and in which the further condenser means comprises two condensers, one connected to discharge through the said primary winding and the other to discharge through a further primary winding cooperative with the said trigger winding.

9. An electric flash-producing system as claimed in claim 7 and in which the said trigger winding cooperates with the transformer windings.

10. An electric system having, in combination, a gaseous-discharge device having a pair of principal electrodes and a trigger electrode, energy storage means, a charging circuit for storing voltage in the energy storage means, a discharge circuit for the energy storage means connected to the principal electrodes and including normally ineffective means for adding voltage, when effective, in the discharge circuit in series with and in the same polarity as the voltage of the energy storage means, and means for supplying a trigger impulse to the trigger electrode and substantially simultaneously rendering the normally ineffective means effective, thereby to enable the energy storage means to discharge through the discharge circuit in order to produce a discharge between the principal electrodes of the gaseous-discharge device.

11. An electric system having, in combination, a spark-gap device having a pair of principal electrodes and a trigger electrode, energy storage means, a charging circuit for storing voltage in the energy storage means, a discharge circuit for the energy storage means connected to the principal electrodes and including normally ineffective means for adding voltage, when effective, in the discharge circuit in series with and in the same polarity as the voltage of the energy storage means, and means for supplying a trigger impulse to the trigger electrode and substantially simultaneously rendering the normally

ineffective means effective, thereby to enable the energy storage means to discharge through the discharge circuit in order to produce a discharge between the principal electrodes of the spark-gap device.

12. An electric system having, in combination, an electric-discharge device having a pair of principal electrodes and a trigger electrode, a trigger transformer the secondary winding of which is connected between the trigger electrode and one of the principal electrodes, a condenser means for charging the condenser, a discharge circuit for the condenser connected to the principal electrodes and including a saturable-core transformer the windings of which are connected in series with the condenser, and means for supplying a trigger impulse to the trigger transformer to break down the electric-discharge device between the trigger electrode and one of the principal electrodes and substantially simultaneously to apply an impulse to the saturable-core transformer, thereby to enable the condenser to discharge through the discharge circuit to produce a discharge between the principal electrodes of the flash device.

13. An electric system having, in combination, an electric-discharge device having a pair of principal electrodes and a trigger electrode, a trigger transformer the secondary winding of which is connected between the trigger electrode and one of the principal electrodes, a condenser, means for charging the condenser, a discharge circuit for the condenser connected to the principal electrodes and including a saturable-core inductor connected in series with the condenser, and means for supplying a trigger impulse to the trigger transformer to break down the electric-discharge device between the trigger electrode and one of the principal electrodes and substantially simultaneously to apply an impulse to the saturable-core inductor, thereby to enable the condenser to discharge between the principal electrodes of the flash device.

No references cited.