May 23, 1950 H. W. LORD 2,509,005

FLASHTUBE TRIGGERING CIRCUITS

Filed Oct. 17, 1949 2 Sheets-Sheet 1

Fig. 1.

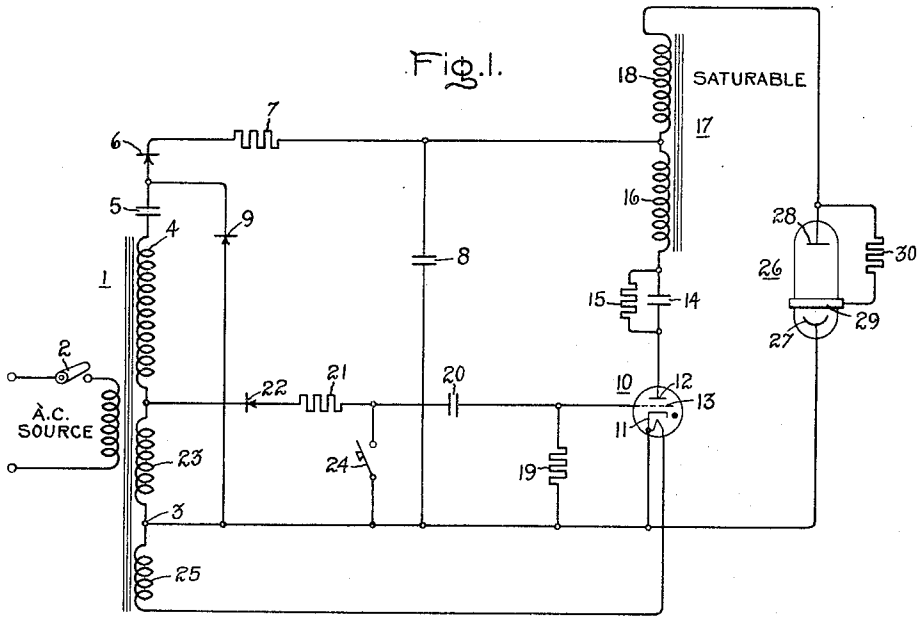
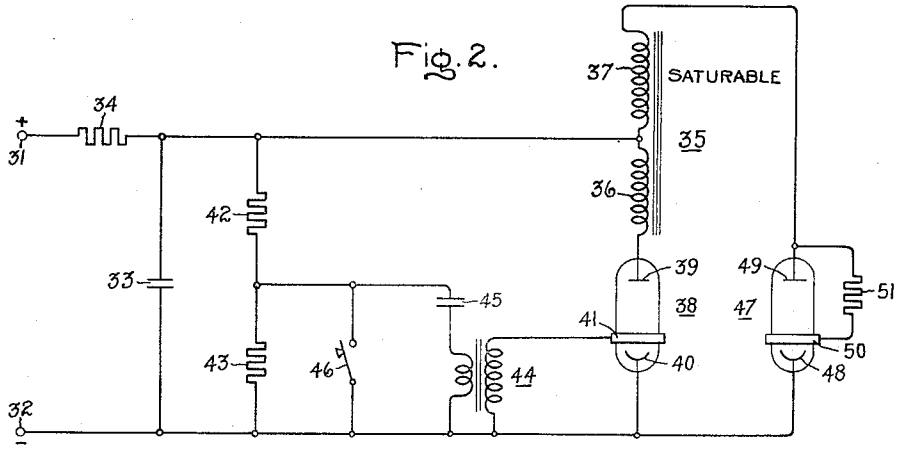


Fig. 2.



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Fig. 3.

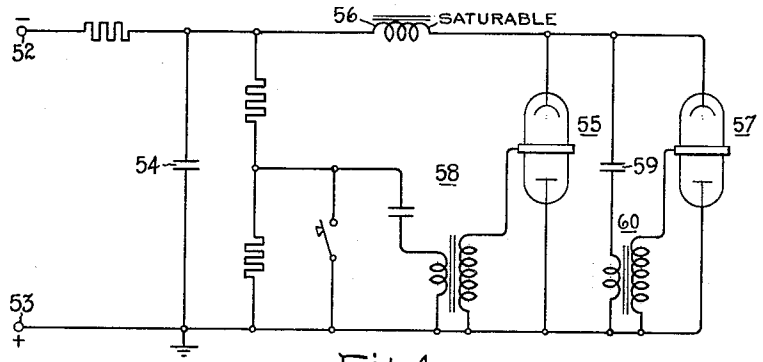


Fig. 4.

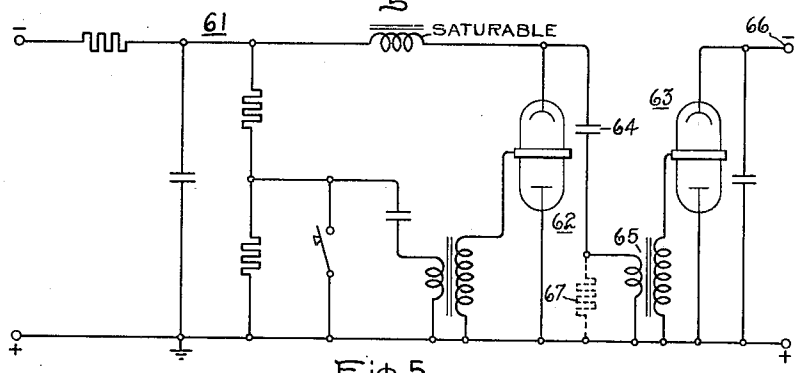
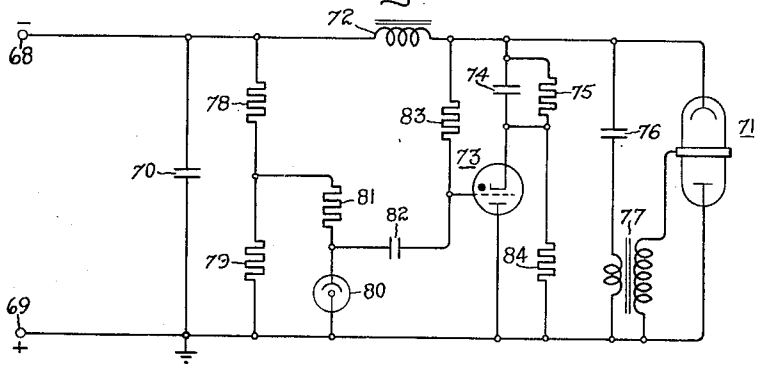


Fig. 5.



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FLASHTUBE TRIGGERING CIRCUITS

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Application October 17, 1949, Serial No. 121,778

34 Claims. (Cl. 315—237)

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My invention relates to flashtube triggering circuits and is a continuation in part of my copending application, Serial Number 703,059, filed October 12, 1946, now abandoned.

Discharge devices of the cold cathode gas or mercury vapor type comonly known in the art as flashtubes have come into general use particularly in photographic and stroboscopic applications mainly because of their ability to emit high intensity illumination and to reach full intensity almost instantaneously. Also, it is usually desirable that the device furnish illumination only during very short increments of time and to furnish such a "flash" at any chosen instant and at any chosen repetition rate.

Such a device usually comprises an anode and cathode as the main electrodes within a gastight glass enclosure in which a small quantity of gas or mercury in liquid or vapor form is placed. A metallic triggering electrode, commonly arranged in contact with that portion of the outer surface of the glass enclosure near the cold cathode, may also be provided. Electrical discharge does not occur when normal anode-to-cathode voltage is applied, since ionization remains sufficiently low to prevent breakdown through the enclosed gas. However, ionization may be increased sufficiently to cause discharge by sharply increasing the voltage gradient in the gas or a portion thereof. Such a voltage gradient increase causes increased ionization since displacement current or condenser charging current in the dielectric consisting of the enclosed gas results, which current causes additional ionization. This may be accomplished by applying a voltage pulse between anode and cathode, or between triggering electrode and cathode. The required amplitude of the voltage pulse is less if a triggering electrode is employed.

Such discharge continues as long as the anode-to-cathode voltage exceeds a critical value below which current flow stops. Thus a source of anode-to-cathode voltage capable of supplying energy and of sharply dropping load characteristic must be provided if "flashes" of short duration are desired. Further, a large triggering voltage must be supplied at the instant illumination is desired.

Where a plurality of flashtubes are to be simultaneously discharged it is desirable that the triggering current should not be increased beyond a magnitude which relatively small circuit making and breaking contacts, such as shutter contacts on a camera, may safely handle without additional relaying components. At the same time, it is desirable to employ a relatively simple control circuit as for single flashtube operation without employing duplicate triggering or relay circuits for the additional flashtubes.

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It is an object of my invention to provide a new and improved circuit which supplies reliable and adequate triggering voltage and adequate energy to the main discharge.

It is another object of my invention to provide a new and improved circuit for a cold cathode gas or mercury vapor luminescent discharge device which is simple and compact and supplies all requirements of the device.

It is another object of my invention to provide an improved triggering circuit for multiple flashtube operation.

It is a further object of my invention to provide a flashtube circuit arrangement for triggering of one or more slave flashtubes in response to the triggering of a first flashtube.

According to my invention, I employ in a circuit for producing light by a direct current discharge through one or more flashtubes, a saturable core inductance device connected in series between the direct current source and the flashtube load, together with a switching arrangement for suddenly impressing a part or all of the voltage of the source across the inductance device. Due to the initially high permeability of the inductance device core, very little current flows through the inductance device after the voltage is impressed until the core saturates, thus terminating the voltage pulse. This voltage pulse is employed to trigger one or more flashtubes, the inductance device being so designed as to present but little impedance to a large discharge current while its core is saturated. The switching arrangement for impressing the voltage pulse across the winding may itself be a flashtube and associated triggering circuit, which thus act as a master unit to initiate simultaneous operation of one or more slave flashtubes.

The features which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the drawings in which Fig. 1 represents a flashtube triggering and supply circuit embodying my invention, and Figs. 2, 3, 4, and 5 are modifications.

Referring now to Fig. 1, a triggering and energizing circuit is shown which may be energized from an A. C. source through the primary of

transformer 1. The usual switch 2 is provided in the primary circuit of transformer 1 for energization or deenergization of the circuit. A voltage doubler rectifying circuit, supplied by the secondary 3—4 of transformer 1, consists in part of condenser 5, rectifier 6, isolating resistor 7, and condenser 8 connected in series across secondary 3—4 with the rectifier 6 allowing current flow in the same direction as the order in which the elements are enumerated. Another rectifier 9 is connected across the serially connected secondary 3—4 and condenser 5 for current flow through rectifier 9 from terminal 3 of secondary 3—4 towards the junction between condenser 5 and rectifier 6.

When energized, terminal 3 becomes positive with respect to terminal 4 during one-half of each cycle of A. C. voltage. During this time rectifier 9 becomes conductive and charges condenser 5 and rectifier 6 remains nonconductive. During the next half cycle terminal 4 becomes positive with respect to terminal 3 and rectifier 6 becomes conductive and essentially double the voltage of secondary 3—4 is impressed across the resistance 7 and condenser 8 in series. Thus, condenser 8 becomes charged to a voltage double the maximum instantaneous voltage of secondary 3—4 if an A. C. voltage is impressed on transformer 1 for a time not less than a minimum time dependent upon the values of resistance 7 and condenser 8.

The voltage of condenser 8 is made available across a series circuit consisting of primary 16 of a saturable core transformer 17, condenser 14 shunted by resistance 15, and a normally open switching device such as the normally nonconducting gaseous discharge tube 10 connected across condenser 8 with the cathode 11 of tube 10 connected to the negatively charged plate of condenser 8. Anode 12 of tube 10 is connected to one terminal of condenser 14. Control grid 13 of tube 10 is held at zero normal bias voltage by resistor 19 connected from cathode 11 to grid 13. Resistor 19 is also part of a circuit consisting of condenser 20, isolating resistor 21, and rectifier 22 connected in series across a portion 23 of secondary 3—4 of transformer 1. Rectifier 22 is connected to allow current flow when terminal 3 is positive with respect to terminal 4 of secondary 3—4, thereby allowing condenser 20 to become charged to the maximum instantaneous voltage of coil 23 with its positive terminal connected to the junction of grid 13 and resistor 19. Condenser 20 and resistor 19 in series are shunted by a discharge keying device 24, the purpose of which will be explained. The cathode heater of tube 10 may be supplied from the secondary coil 25 of transformer 1.

A space discharge tube 26, such as is commonly known in the art as a flashtube, having a cold cathode 27, anode 28 and triggering electrode 29 is employed as the controlled source of illumination. The voltage of condenser 8 is made available to tube 26 by connecting cathode 27 to one side of condenser 8 and anode 28 to the other side of condenser 8, the latter connection being made through the secondary winding 18 of transformer 17. The trigger electrode 29 is connected to anode 28 through a resistance 30. Resistor 30 is employed to prevent sustained arcing between cathode and trigger electrode over the exterior surface of the tube, if such arc is initiated by any cause.

When the circuit is energized and key 24 is left open, tube 10 and tube 26 are both nonconducting. Condenser 8 is charged to a voltage equal to twice the maximum instantaneous voltage of secondary coil 3—4 of transformer 1, as previously described. Condenser 20 is charged to a voltage equal to the maximum instantaneous voltage of secondary coil 23 of transformer 1 with the plate connected to grid 13 positively charged. Grid 13 is at a negative potential with respect to cathode 11 of tube 10 as caused by voltage drop in resistor 19 while condenser 20 is being charged and arrives at zero potential when condenser 20 is fully charged. Tube 10 is of a type which requires a positive grid voltage to initiate a discharge through it. It has preferably a voltage rating in excess of the desired voltage charge on condenser 8, thereby preventing the possibility of loss of grid control at zero bias.

The anode to cathode voltage on tube 10 is normally the full voltage of condenser 8 since no current is flowing in primary 16 of transformer 17 and condenser 14 is uncharged. The anode to cathode voltage of tube 26 is also equal to the full voltage of condenser 8 since there is neither induced voltage in nor current through secondary 18 of transformer 17. Further, electrode 29 is at anode potential since there is no current in resistor 30.

Actuation of key 24 drives grid 13 of tube 10 positively to a voltage equal to that of condenser 20 and initiates a discharge from cathode 11 to anode 12. Resistor 21 prevents shorting of secondary 23 of transformer 1 while key 24 is depressed. It may be preferable to employ a low RC time constant in the circuit consisting of condenser 20 and resistor 19 in series to insure return of grid 13 to control status immediately after tube 10 again becomes nonconducting. It is apparent that grid 13 may be controlled by other means such as an amplifier or electronic switching means without departing from the principles of my invention.

When tube 10 becomes conductive, a voltage appears across primary 16 of transformer 17 to an amount less than condenser 8 voltage by the cathode-anode voltage of tube 10 necessary to sustain tube current flow. Current then builds up in primary 16 and condenser 14 charges up. When insufficient voltage remains across tube 10 to sustain current flow through it tube 10 returns to a nonconducting status, causing current flow through it and through the primary 16 to cease. Condenser 14 then returns to normal zero charge by discharging through the shunting resistor 15. Therefore, condenser 14 shunted by resistor 15 constitutes automatic resetting means responsive to integrated current flow for causing the switching device 10 to return to its normally open circuit condition.

When a D. C. voltage is suddenly applied across primary 16 as by causing tube 10 to become conductive, a similar voltage appears across secondary 18 whose magnitude bears the same ratio to the primary voltage as the turn ratio of transformer 17. This secondary voltage adds to the voltage of condenser 8 to cause a sudden increase of voltage gradient within tube 26, thereby causing tube 26 to become conductive.

When tube 26 becomes conductive, the voltage across tube 26 suddenly decreases to a value just sufficient to maintain discharge through it. Thus the voltage across secondary 18 must necessarily change in direction and amount at the instant tube 26 becomes conductive. This voltage change may be considered as an induced voltage in secondary 18 caused by the initiation of current

flow through it as required by tube 26. As the current flow to tube 26 increases, an induced voltage remains to an extent dependent upon the rate of change of flux linking secondary 18, which in turn is complexly dependent upon current and the instantaneous reluctance of the magnetic circuit linking secondary 18. When tube 26 becomes fully conductive the magnetic circuit of transformer 17 is saturated as stated previously, the induced voltage of secondary 18 is consequently decreased to a small value, and secondary 18 may then be considered as a saturated reactor essentially decoupled from primary 16 and of relatively low inductance value. Energy is, therefore, supplied to tube 26 from condenser 8 at a voltage somewhat less than the decreasing voltage of condenser 8. Discharge of condenser 8 decreases its voltage and when this voltage becomes insufficient to sustain discharge through tube 26, tube 26 again becomes nonconducting. Isolating resistor 7 prevents undue current flow in secondary 3—4 while tube 10 and tube 26 are conductive.

The inductive effect of secondary 18 may tend to prolong the discharge time of tube 26 since a current decrease through it in the range of current values below saturation current induces a voltage in secondary 18 by self induction of additive polarity with respect to the voltage of condenser 8. This may be compensated by using a smaller capacity for condenser 8 which will cause a more rapid decrease in voltage across condenser 8 when tube 26 is conducting. However, a higher voltage charge on condenser 8 should then be employed if the total energy available for illumination is to be the same.

The sequence described above may be repeated at any repetition rate which will allow sufficient time for recovery of proper charges on condensers 8 and 20 before the next discharge sequence occurs.

As shown in Fig. 2 a modification of a flashtube triggering circuit embodying my invention is employed to trigger a second or slave flashtube from the operation of a first or master flashtube. Accordingly, circuit terminals 31 and 32 are connected to the positive and negative terminals, respectively, of a direct current voltage source to appropriately charge a condenser 33. A resistor 34 is preferably connected in series between the condenser 33 and the voltage source to regulate the condenser charging rate as desired. A saturable core transformer 35, arranged similarly to the transformer 17 in Fig. 1, has its common connection for one end of the primary winding 36 and one end of the secondary winding 37 connected to the positively charged plate of the condenser 33. A gaseous discharge device or flashtube 38 designed to emit light upon the passage of a substantial current between its anode 39 and cathode 40 is connected in circuit with its anode connected to the other end of the primary winding 36 and its cathode connected to the negatively charged plate of condenser 33. The flashtube 38 has a triggering electrode 41 and is preferably of a type arranged to be triggered by a relatively low power pulse applied between its triggering electrode 41 and cathode 40 so that no gaseous discharge tube need be employed in its triggering circuit. A satisfactory voltage source for the triggering pulse may be suitably provided by connecting voltage divider resistors 42 and 43 in series across the plates of the condenser 33. The primary winding of a triggering transformer 44 is connected to the negative plate of the condenser 33 and to the common connection of the voltage divider resistors 42 and 43 through a triggering condenser 45, and the secondary winding of the triggering transformer 44 is connected between the triggering electrode 41 and the cathode 40 of the flashtube. The triggering impulse is provided by closing a switch 45 which is shunted across the voltage divider resistor 43, thereby impressing the full voltage of the condenser 33 across the series connected triggering condenser 45 and primary winding of the triggering transformer 44. The resultant surge of voltage across the transformer primary is suitably multiplied in its secondary winding by the transformer turns ratio to breakdown the flashtube 38 and initiate current flow between its main electrodes. The switch 46 may be, for example, the contacts on the shutter mechanism of a camera, when the apparatus is employed in photographic applications.

Upon triggering of the master flashtube 38 its anode-to-cathode voltage is reduced from substantially the full voltage of the condenser 33 to a value just sufficient to maintain discharge, thus suddenly impressing the greater part of the voltage of condenser 33 across the primary winding 36 of the saturable core transformer 35. Accordingly, as described in the operation of the saturable core transformer 17 of Fig. 1, a triggering voltage pulse appears across the secondary winding 37 of the transformer 17 whose magnitude bears the same ratio to the primary voltage as the turns ratio of the transformer. A second or slave flashtube 47 is connected to the energizing circuit with its cathode 48 connected to the negative plate of the condenser 33 and its anode 49 connected to the end of the secondary winding 47. As previously described with respect to Fig. 1 the triggering electrode 50 of the slave flashtube 47 is connected to the anode 49 through a series resistor 51, the resistor serving to prevent the possibility of sustained arcing between the cathode and triggering electrode. After the core of the transformer 36 saturates, the primary and secondary windings present a relatively small impedance to current flow therethrough so that a large conductive current flows through flashtubes 38 and 47 from the charged condenser 33. Since it is desired that both flashtubes carry a substantial portion of the discharged current, no current limiting or resetting circuit elements corresponding to the condenser 14 and the resistor 15 in Fig. 1 are employed in series with the master flashtube 38. Flashtubes 37 and 48 may have the same operating characteristics, in which case it is expedient that the primary and secondary windings of the transformer 36 have the same resistance, thus assuring an equal division of current through the flashtubes. The division of the current between the flashtubes may be adjusted in any other manner as desired by any well-known means.

Since the triggering excitation for the slave flashtube 47 is derived from the discharge circuit of the master flashtube 38, no additional load is placed on the master flashtube triggering circuit, and accordingly more than one slave flashtube may be readily employed. In view of the low triggering energy required for simultaneously flashing a plurality of flashtubes, long operating life can be obtained from relatively light switch contacts, such as may be conveniently employed in a camera shutter mechanism.

In the modification of my invention illustrated by Fig. 3 a saturable reactor is employed for

triggering a plurality of flashtubes, the flashtubes suitably being of the type having a cathode and anode as the main electrodes, and a triggering electrode designed to render the tube conductive when a voltage impulse is applied between the triggering electrode and one of the main electrodes. As shown in the figure, terminals 52 and 53 of the charging circuit are connected respectively to the negative and positive terminals of a D.-C. voltage source, and a condenser 54, shown with its positively charged plate grounded, is connected to the terminals. A master flashtube 55 has its main electrodes connected across the condenser 54 with the winding of a saturable reactor 56 connected in series between the flashtube cathode and negatively charged plate of condenser 54. The reactor may suitably comprise a substantially closed thinly-laminated ferromagnetic core with a coil consisting of a few turns of heavy copper wire or ribbon, the reactor being arranged to saturate within a few microseconds after a direct current voltage is impressed across it. A second or slave flashtube 57 is connected with its main electrodes paralleling the corresponding electrodes of the master flashtube 55.

A suitable triggering circuit 58 for initiating the discharge in the master flashtube 55, similar to that provided in the embodiment of my invention illustrated by Fig. 2, is employed.

When the flashtube 55 begins to conduct, substantially all of the voltage of the condenser 54 is impressed across the terminals of the saturable reactor 56. In view of the relatively steep wave front of the voltage thus impressed, the sudden drop of voltage across the main electrodes of the master flashtube 55 is readily utilized in triggering the slave flashtube 57. Accordingly, a triggering condenser 59 and the primary winding of a triggering transformer 60 are connected in series across the slave flashtube cathode and anode terminals. The condenser and transformer winding act as a differentiating circuit, and the steep wave front of the voltage drop acros the flashtube 55 appears as a sharply peaked voltage impulse across the primary winding of the triggering transformer 60. Accordingly, a corresponding voltage pulse appears across the secondary of the trigger transformer, multiplied by the turns ratio thereof. Since the trigger transformer secondary winding is connected between the trigger electrode and anode of the slave flashtube 57, a discharge is thus initiated between its main electrodes in response to the discharge between the main electrodes of the master flashtube 55.

Inasmuch as the core of the saturable reactor 56 saturates after the flow of current through its winding, the voltage drops sharply a few microseconds after the voltage of condenser 54 is impressed across it. Accordingly, as described previously, with respect to Fig. 2, a large discharge current from the condenser 54 flows through the saturable reactor 56 and is divided between the master and slave flashtubes 55 and 57 respectively, rendering both luminescent.

As in the embodiment described in Fig. 2, it is obvious that, without departing from the spirit of my invention, more than one slave tube may be utilized. In a physical arrangement of the slave tube 57 with respect to the master tube 55, it is desirable, of course, that the circuit connections between the slave tube triggering transformer 60 and the slave tube 57 be relatively short, although the other conductors may be of a substantial length without impairing the operation of the slave circuit. It is to be noted that no secondary winding on the saturable reactor 57 is utilized as in the saturable core inductance devices employed in the embodiment shown in Figs. 1 and 2.

Referring to Fig. 4, a flashtube energizing and triggering circuit 61 is provided for a master flashtube 62 similar to the master flashtube circuit shown in Fig. 2, but the discharge energy for a slave flashtube 63 is provided by a separate D.-C. voltage source. A slave tube triggering condenser 64 and a triggering transformer 65 are connected in series between the anode and cathode of the master flashtube 62 for triggering the slave flashtube 63 in a manner previously described. One satisfactory physical arrangement of the slave tube triggering components is suggested by Fig. 4 in that the triggering condenser 64 may be physically positioned near the master flashtube assembly so that the relatively long leads from the other plate of the triggering condenser and the anode of the master flashtube 62 need have no potential between them except the triggering pulse. These leads preferably extend as a coaxial cable to the primary winding terminals of the slave tube triggering transformer 65. A separate energizing circuit 66 for the slave flashtube 63 eliminates the need for conductors other than for triggering between master and slave flashtubes. A surge-limiting resistor 67 is shown in dotted outline between the cable conductors near the master flashtube unit junction and may be used to prevent dangerously high potentials at the cable terminals when the slave unit is disconnected.

In the modification of my invention shown in Fig. 5, a flashtube is triggered in response to a relatively weak signal, such as provided by the operation of a photo tube. Again input terminals 68 and 69 of the flashtube energizing circuit are arranged to be connected to the negative and positive terminals, respectively, of a direct current voltage source. A condenser 70 is connected across the input terminals so that it may be suitably charged to provide a discharge current between the main electrodes of a flashtube 71. A saturable reactor 72 is connected in series between the negatively charged plate of the condenser 70 and the cathode of the flashtube 71, and the discharge circuit is completed by connecting the positively charged plate of the condenser 70 to the flashtube anode.

A gaseous discharge device 73, such as a thyratron which may be triggered by a sufficiently positive signal applied to its grid or control electrode, is connected in parallel with the flashtube 71, through a current limiting and resetting circuit comprising a condenser 74 shunted by a resistor 75. Substantially the full voltage of the condenser 70 is impressed across the saturable reactor 72 when the thyratron 73 is rendered conductive, and a differentiating circuit comprising a condenser 76 and the primary winding of a triggering transformer 77, is connected in the manner previously described with respect to Fig. 3, to provide a positive triggering impulse in the secondary winding of the triggering transformer 77. Since the secondary winding is connected between the triggering electrode and anode of the flashtube 71, the flashtube is rendered conductive upon the firing of the thyratron 73.

To provide a control voltage for triggering the thyratron 73, a pair of voltage divider resistors 78 and 79 are connected in series across the con-

denser 70. A phototube 80 is employed as a circuit closing means and is connected in series with a dropping resistor 81 having a very high ohmic value, the phototube and dropping resistor being shunted around the voltage divider resistor 79 to place a potential across the phototube. The phototube cathode is coupled to the grid of the thyratron 73 through a condenser 82 which transmits a positive triggering pulse to the grid when the phototube is suddenly rendered conductive and its cathode thereby made more positive. Conventional negative bias is provided for the thyratron 73 by a grid biasing resistor 83 connected between the thyratron grid and the cathode of the flashtube 71, and a resistor 84 connected between the thyratron cathode and flashtube anode. This modification of my invention as shown in Fig. 5, has a special utility as an independent slave flashtube unit in that the phototube 80 may be arranged to conduct in response to the light flash from a remote master flashtube.

In each of the modifications described, I have utilized the peculiar non-linear characteristic of a saturable reactor so that a high impedance is presented to a steep wave front of a suddenly impressed voltage for providing a triggering pulse and a relatively low reactor impedance is presented after saturation of the core to permit a substantial discharge current through the series circuit. It will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention. I, therefore, aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent is:

1. In combination, a condenser, means for charging said condenser, a space discharge tube possessing an anode, cathode and triggering electrode, means including an impedance 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.

2. 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.

3. 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.

4. 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.

5. 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 nonconducting, 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.

6. 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.

7. 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.

8. 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.

9. 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 con-

nected 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.

10. 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.

11. 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.

12. 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, said second capacitor and the primary of said transformer being connected in series in the order named between the anode of said discharge tube and one plate of said first capacitor, the other plate of said first capacitor being connected to the cathode 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.

13. In combination, a flashtube having a cathode, anode, and triggering electrode, a resistor connecting the flashtube anode and triggering electrode, a first capacitor having one of its plates connected to the flashtube cathode, a saturable core transformer having its secondary connected between the other plate of said first capacitor and the flashtube anode, 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, said second capacitor and the primary of said transformer being connected in series in the order named between the anode of said discharge tube and one plate of said first capacitor, the other plate of said first capacitor being connected to the cathode of said discharge tube, a first resistor connected in parallel with said second capacitor, a second resistor connecting the grid and cathode of said discharge tube, a source of negative voltage relative to the discharge tube cathode, a third capacitor connected between said source of negative voltage and the discharge tube grid, and switching means adapted upon actuation to suddenly short out the negative voltage applied to said third capacitor, so that the grid of the discharge tube is driven positive and the tube becomes 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.

14. In combination, a flashtube having a cathode, anode, and triggering electrode, a resistor connecting the flashtube anode and triggering electrode, a first capacitor having its first plate connected to the flashtube cathode, a saturable core transformer having its secondary connected between the second plate of said first capacitor and the flashtube anode, a first voltage source connected to charge the first capacitor with its first plate positive relative to its second plate, a second capacitor, a normally non-conductive grid-controlled discharge tube, said second capacitor and the primary of said transformer being connected in series in the order named between the anode of said discharge tube and the first plate of the first capacitor, the cathode of said discharge tube being connected to the second plate of the first capacitor, a first resistor connected in parallel with said second capacitor, a second resistor connecting the grid and cathode of said discharge tube, a second voltage source adapted to supply a voltage negative with respect to the cathode of said discharge tube, a third resistor and a third capacitor connected in series in the order named between the second voltage source and the grid of said discharge tube, and switchng means adapted upon actuation to suddenly establish a short circuit connection between the plate of the third capacitor connected to the third resistor and the cathode of the discharge tube, so that the grid of the discharge tube is driven positive and the tube becomes 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.

15. 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.

16. An electric circuit comprising a saturable core inductance device and a first gaseous discharge device connected in series, means for ap-

plying 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.

17. 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.

18. 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.

19. 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.

20. 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.

21. 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.

22. 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.

23. 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.

24. 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 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 source 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.

25. 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.

26. An energizing circuit for a plurality of flashtubes comprising a unidirectional voltage source connected to sustain a flow of current through said flashtubes, a saturable core transformer having its primary winding serially connected in circuit between a first of said plurality of flashtubes and said source and having its secondary winding serially connected in circuit between a second of said flashtubes and said source,

means for rendering said first of said flashtubes conductive to thereby apply a voltage impulse to the primary winding of said transformer of proper plurality to induce a voltage in the secondary winding having a polarity additive to said source.

27. An energizing circuit for a plurality of flashtubes comprising a condenser, means for charging said condenser to a voltage sufficient to sustain a flow of current through said flashtubes, a saturable core transformer having its primary winding serially connected in circuit between a first of said flashtubes and said source and a secondary winding serially connected in circuit between a second of said flashtubes and said source, and means for rendering said first of said flashtubes 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.

28. 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.

29. In a flashtube energizing circuit, apparatus for producing a triggering impulse in the secondary winding of a triggering transformer comprising a first capacitor, means for charging said first capacitor, a saturable reactor, a normally non-conductive grid-controlled discharge device, said first capacitor, said reactor, and said discharge device being serially connected in a closed circuit loop, means for applying a triggering voltage to the grid of said discharge device to render said discharge device conductive, and a differentiating circuit comprising a serially connected second capacitor and the primary winding of said triggering transformer connected in parallel with said discharge device.

30. An energizing circuit for a plurality of flashtubes comprising an energy storage means connected to sustain a flow of current through said flashtubes, means for charging said storage means, a saturable reactor serially connected between said flashtubes and said storage means, means for rendering one of said flashtubes conductive to cause a sudden change of voltage across said reactor before saturation thereof, means for rendering another of said flashtubes conductive in response to said sudden change of voltage, said inductance device core being saturated by conduction of current of said flashtubes whereby substantially the full voltage of said source is applied to said flashtubes to cause said flashtubes to become luminescent by the passage of currents therethrough.

31. An energizing circuit for a plurality of gaseous discharge devices comprising a unidirectional voltage source connected to sustain a flow of current through said flashtubes, a saturable core inductance device serially connected between said gaseous discharge devices and said source, means for rendering one of said discharge devices conductive to establish a sudden change of voltage across said inductance device before saturation thereof, and triggering means for rendering another of said discharge devices conductive in response to said sudden change of voltage, said triggering means comprising a capacitor and a transformer having two windings, said capacitor and one of said windings being connected in series across said one of said discharge devices, and the other of said windings being connected between a control electrode and main electrode of said another of said discharge devices, said inductance device being saturated by the conduction current of said flashtubes whereby substantially the full voltage of said source is applied to said discharge devices.

32. An energizing circuit for a plurality of flashtubes comprising a first capacitor, means for charging said first capacitor, a saturable core reactor, circuit means for connecting said reactor and one of said plurality of flashtubes in series across said first capacitor, means for rendering said one flashtube conductive to impress an impulse voltage across said reactor, and triggering means responsive to said impulse voltage for rendering another of said flashtubes conductive, said triggering means comprising a second capacitor, a transformer, circuit means for connecting said second capacitor and the primary winding of said transformer across said one flashtube, and circuit means connecting the secondary winding of said transformer to said another of said flashtubes.

33. An energizing circuit for a plurality of flashtubes each having a pair of main electrodes and a triggering electrode, which comprises a first capacitor, means for charging said first capacitor, a saturable reactor, circuit means for connecting the main electrodes of at least one of said plurality of flashtubes across said first capacitor through said reactor, means for triggering said one flashtube to thereby impress an impulse voltage across said reactor, and triggering means responsive to said impulse voltage for rendering another of said flashtubes conductive, said triggering means comprising a second capacitor, a transformer having a primary and secondary winding, circuit means for connecting said second capacitor and the primary winding of said transformer across said one flashtube, and circuit means connecting the secondary winding of said transformer between one of the main electrodes and the triggering electrode of said another of said flashtubes.

34. An energizing circuit for a plurality of flashtubes comprising a first capacitor, means for charging said first capacitor, a saturable core reactor, circuit means for connecting each of said plurality of flashtubes across said first capacitor in series with said reactor, means for rendering said one of said plurality of flashtubes conductive to impress an impulse voltage across said reactor device, and triggering means responsive to said impulse voltage connected to render another of said flashtubes conductive, said triggering means comprising a second capacitor and a transformer with circuit means for connecting said second capacitor and a winding of said transformer across said one flashtube.

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No references cited.