Aug. 16, 1949. H. E. EDGERTON 2,478,904

LIGHT-FLASH-PRODUCING SYSTEM

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Fig. 1.

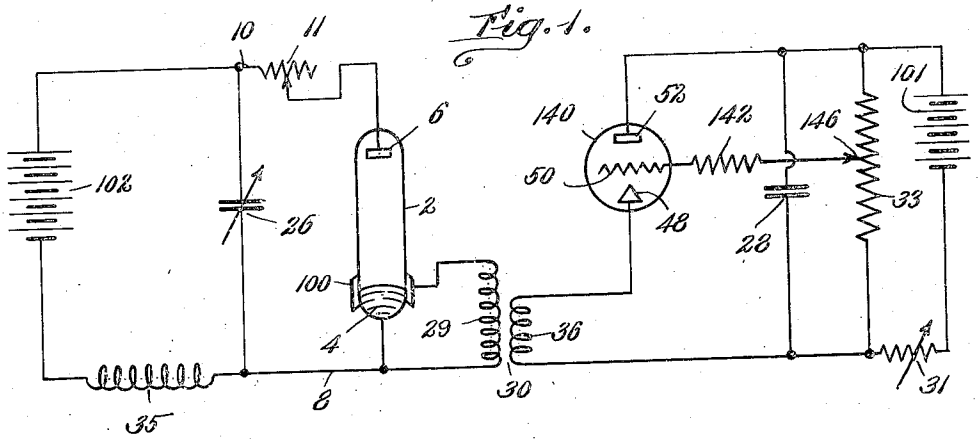


Fig. 2.

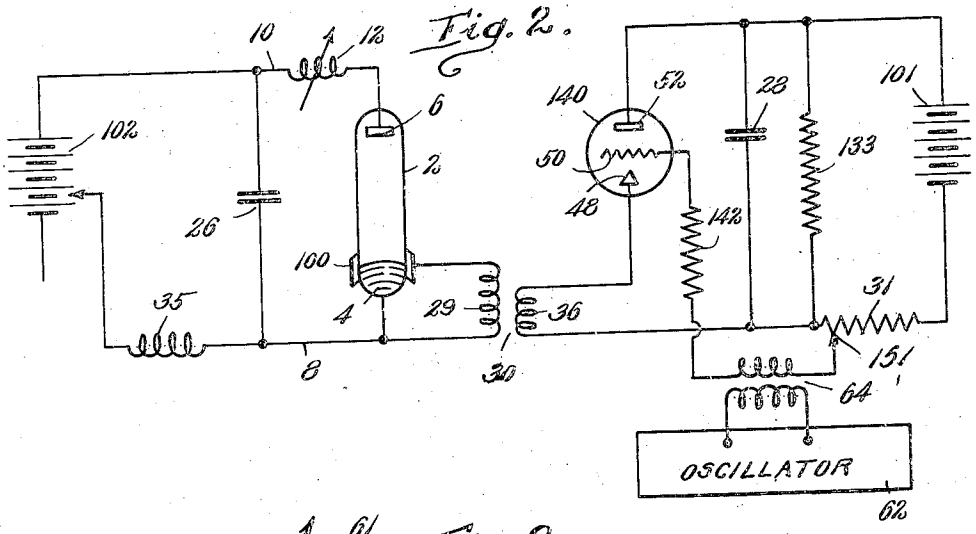
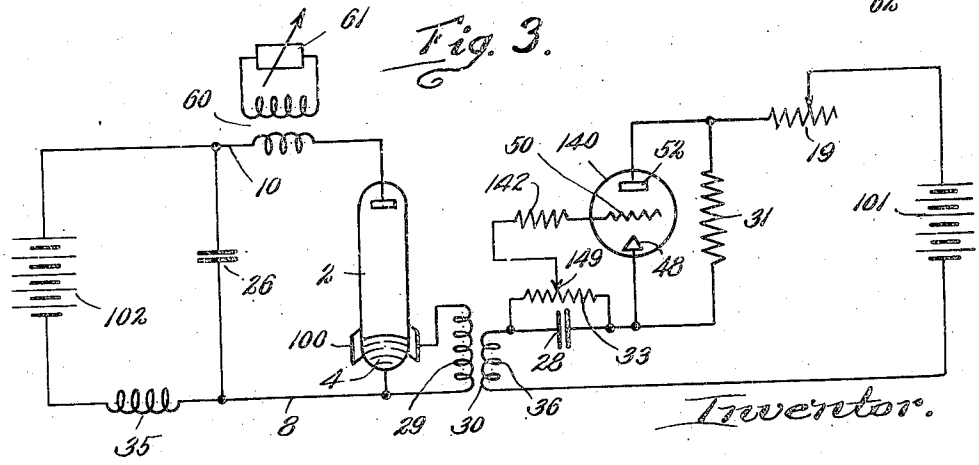


Fig. 3.



Inventor.

Harold E. Edgerton

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Fig. 4.

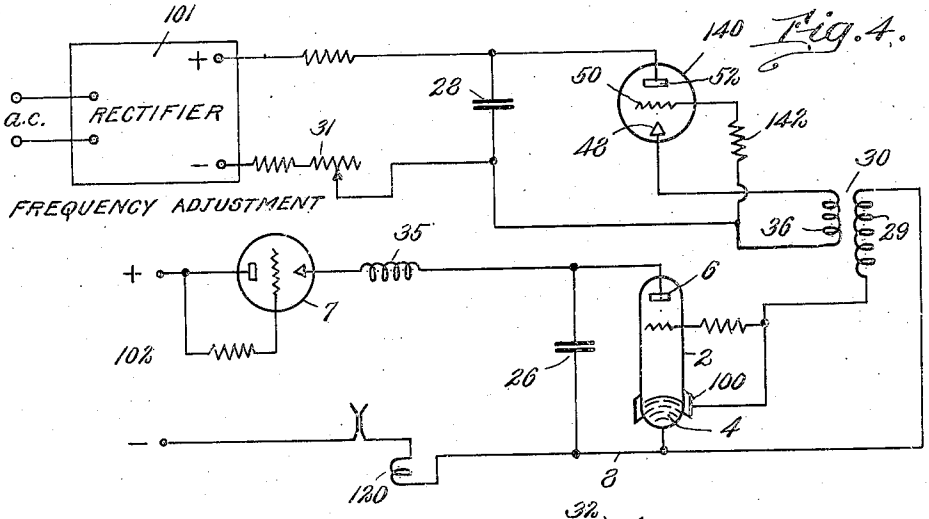


Fig. 5.

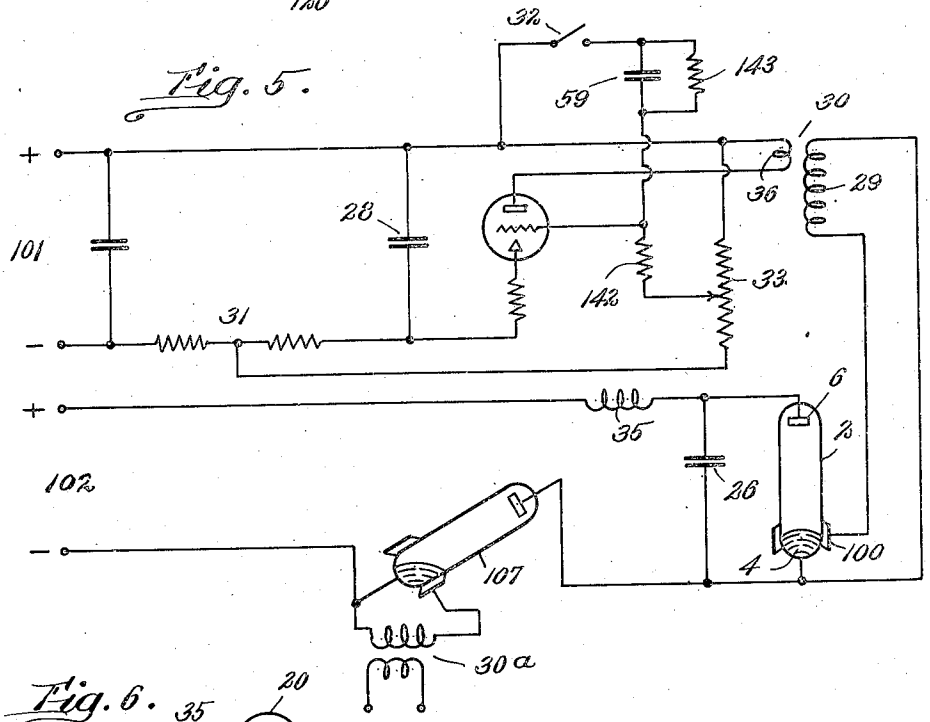
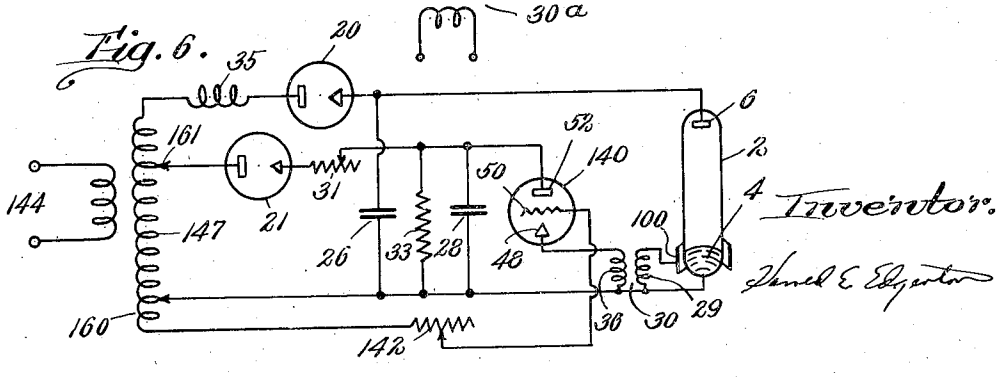


Fig. 6.



Inventor.
Harold E. Edgerton

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2,478,904

LIGHT-FLASH-PRODUCING SYSTEM

Harold E. Edgerton, Belmont, Mass.

Application December 30, 1939, Serial No. 311,724

16 Claims. (Cl. 315—261)

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The present invention is related to electric-energy flash-producing systems in which the discharge of a flash condenser is employed for such purposes as to produce a single light flash or a repetition of light flashes of short duration and high intensity, as in flash-photography and stroboscopic work. The present application is a continuation-in-part of application, Serial No. 685,501, filed August 16, 1933.

In the said application, there is disclosed a new and improved system for producing strong and intense substantially uniform electric-energy light flashes by means of a very small amount of electric energy discharged from a condenser quickly, reliably and accurately at high frequency through a gaseous-conductor lamp. This system is simple and rugged in construction, light in weight, portable and self contained, easily operable, without moving parts (except, in some cases, for a contactor), and thoroughly effective and reliable in operation.

Though it is explained, in the said application, that the quantity of light of the light flashes is determined by the amount of energy in the condenser and by circuit conditions, that feature, in order to maintain a line of division, is not claimed in the said application. It is a feature that is claimed in the present application.

The invention will now be described 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; Figs. 2 and 3 are modifications of the same; and Figs. 4, 5 and 6 illustrate modified stroboscope light-source circuits embodying an efficient method of charging the condensers.

As described in the said application, a luminescent vapor electric gaseous-discharge flash lamp or flash tube 2 or 107 is provided with two internal main or principal electrodes 4 and 6 in a glass-tube envelope. Other apparatus than the illustrated lamp 2 may also be used in accordance with the present invention. The principal electrodes 4 and 6 define a principal-current path for the lamp 2. The lamp 2 is described in the said application as of the low-impedance mercury-arc gaseous-conductor type, the internal electrode 4 being shown as in the form of a liquid pool of mercury, used for a cathode, and the internal electrode 6 serving as the anode or plate. The remarks throughout this specification concerning mercury-arc tubes or lamps apply equally well to tubes or lamps filled with other gases, with or without mercury vapor.

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The pressure of the mercury or other gas or vapor in lamps of this nature is normally of such value as to render the lamp 2 normally non-conductive or ineffective. The gas may become ionized, however, in response to the energization of a normally unenergized control-grid triggering or starting electrode 100, to facilitate the starting of the tube 2, by initiating current flow in the principal-current path including the gaseous medium of the tube 2 defined by the principal electrodes 4 and 6. This initiation and starting are effected through the medium of a starting-current path extending from the starting electrode 100.

The electrode 100 is shown in the said application as an external metal-band condenser electrode, situated around the glass of the envelope of the lamp 2, outside the mercury pool 4, opposite to the meniscus of the mercury. Other types of control-grid or starting electrodes, including electrodes of the internal type, may also be employed.

A suitable source of direct-current energy is shown as constituted of a battery 102. The positive terminal of the battery 102 is shown connected by a wire-conductor lead 10 to the anode 6, to render the anode positive, and the negative terminal by a wire-conductor lead 8 to the cathode 4. Potential is thus supplied across the principal current path between the cathode 4 and the anode 6. The direct-current voltage may, however, be derived from any desired conventional source of alternating energy of suitable voltage and frequency through a transformer. The primary winding 144 of the transformer illustrated in Fig. 6 is shown connected to the alternating-current source, and the secondary winding 147 to the gaseous-conductor lamp 2 through a thermionic or gaseous-discharge rectifier circuit. The thermionic or gaseous-discharge rectifier circuit may comprise a thermionic or gaseous-discharge half-wave rectifier tube 20, as shown in Fig. 6, or a common type of full-wave thermionic rectifier-and-filter arrangement, comprising thermionic or gaseous-discharge half-wave rectifier units, as shown in the said application, Serial No. 685,501. The secondary winding 147 of the transformer 148 is shown connected to the anode of the thermionic tube 20. Filter condensers and an inductance or inductances, not shown, may be provided as part of the conventional source of direct current.

A main discharge flash capacitor or condenser 26 is normally charged with energy at a predetermined rate from the source of direct current

to the full potential of that source. This charging may be effected by connecting the flash condenser 26 to the source of direct current in any desired manner, as by means of the wire conductors 8 and 10. The flash condenser 26 is shown connected to the source of direct-current potential in parallel with the principal electrodes 4 and 6. The electrodes 4 and 6 are therefore connected in series with the two terminals of the flash-condenser source of energy at the same time that energy is thus supplied to the flash condenser 26 from the source of direct current. The usual voltage to which the condenser becomes thus charged is from 200 to 2,000 volts.

The charging circuit for the condenser 26 is shown extending from the positive terminal of the battery 102, or from the rectifier 20, by way of the conductor 10, to the corresponding positive terminal of the condenser 26; and from the negative terminal of the battery 102, by way of the conductor 8, to the negative terminal of the condenser 26. A current-limiting charging impedance 35 may be series-connected in the charging circuit of the condenser 26, between the condenser 26 and its charging source of direct current, either in the wire conductor 10, as shown in Figs. 4 and 5, or the wire conductor 8, as illustrated in Figs. 1, 2 and 3.

Because of the dielectric properties of the normally deionized mercury vapor or other gas in the space of the lamp 2, between the cathode 4 and the anode 6, the battery 102 or other direct-current source will before each flash charge the flash condenser 26 through the impedance 35 so that the anode 6 is positive, without any of the energy of the battery 102 traversing that space. A difference of potential of unvarying polarity will therefore be established between the cathode 4 and the anode 6 during the charging of the condenser 26.

After becoming thus charged, the condenser 26, as will presently be more fully explained, may be discharged through the gaseous medium of the lamp 2, between the anode 6 and the cathode 4, in the discharge circuit of the lamp 2. The lamp 2 will be recognized by persons skilled in the art as of the type in which a positive-column discharge may pass between the anode electrode 6 and the cathode electrode 4. The discharge current thus obtained from the flash-condenser source of energy results in the production of an electric-energy light flash through the lamp 2. The major portion of the energy supplied from the flash condenser source of energy in the series-circuit connection between the terminals of the flash condenser 26 and the principal electrodes 4 and 6 is consumed in the positive-column discharge, with the result that the light flash is of high illumination intensity and short duration.

The condenser-discharge circuit is shown extending from the positive terminal of the condenser 26, by way of the conductor 10, directly to the anode electrode 6; and from the negative terminal of the condenser 26, by way of the conductor 8, directly to the cathode electrode 4. The cathode 4 and the anode 6 of the lamp 2 are thus series-connected by the conductors 8 and 10 to the condenser 26 in this condenser-discharge circuit directly across the condenser 26. The connections are such as to enable the condenser 26 to discharge with relative rapidity through the lamp 2 between the anode electrode 6 and the cathode electrode 4 when the lamp 2 becomes conductive.

The impedance 35 should be designed sufficiently large so that, after the discharge of the condenser 26 between the cathode 4 and the anode 6, further current flow between them will be prevented until after the gaseous space in the lamp 2 between the electrodes 4 and 6 shall have again become deionized. The condenser 26 is therefore normally charged to a voltage of unvarying polarity and of magnitude insufficient to effect a discharge of the condenser through the lamp between the electrodes 4 and 6 when the lamp is non-conductive, though sufficient to effect a discharge of the condenser 26 through the lamp between the electrodes 4 and 6 when the lamp is conductive. The impedance 35 should, however, be small enough to permit of the re-establishment of sufficient difference of potential between the cathode 4 and the anode 6 to enable recharging of the condenser 26 with energy from the direct-current source in time for the next flash. These ends may be attained by rendering the impedance 35 suitably reactive, as by constituting it of a wire conductor comprising a combination of resistance and inductance. The size and characteristics of the impedance 35 should be determined by the characteristics of the flash lamp 2 or other apparatus in connection with which it is used and the desired time interval between the condenser discharges. This feature, as stated in the said application, is claimed in a copending divisional application, Serial No. 688,406, filed August 5, 1946.

As is stated in the said application, Serial No. 685,501, the quantity of stroboscopic light is determined by the amount of energy in the condenser 26 and by circuit conditions. The capacity of the condenser 26 is increased until there is sufficient average light for the particular frequency of flashing and the extraneous illumination. Slow speeds require a larger amount of light per flash than fast speeds to give the same average illumination.

Five possible methods of varying the amount of light are:

1. Changing the capacity, as by varying the capacity 26. The amount of light for each flash is almost proportional to the capacity and the square of the voltage.

2. Changing the voltage, as indicated by the tapped input supply battery or power supply 102, in Fig. 2. There are many well-known methods of varying the input voltage, either manually or automatically, to suit requirements.

3. Changing the value of a series resistor 11 in the lamp discharge circuit, as indicated in Fig. 1. The light decreases as the resistance increases, since more of the energy is lost in the resistor.

4. Changing the value of an inductance 12 in series with the lamp, in the condenser-discharge circuit, as indicated in Fig. 2. The light is decreased as the inductance is increased. This variable inductance may be of the variometer type, consisting of two coils movable with respect to each other.

5. Changing the secondary impedance 61 of a transformer 60 that is connected in series with the discharge current, as illustrated in Fig. 3. the secondary impedance 61 of this transformer may be inductive, capacitive, resistive, or any combination of these. It may further consist of vacuum or gas-filled tubes, without moving parts, according to methods well known in the art, for automatically controlling the amount of light, in accordance with any desired requirements.

As is also explained in the said application, Serial No. 685,501, the discharge of the flash condenser 26 through the condenser-discharge circuit above described is initiated by energizing the normally unenergized starting electrode 100, under the control of a trip circuit. The trip circuit is shown comprising a second normally non-conductive or ineffective gaseous-discharge trigger-tube device 140, a small auxiliary capacitor or condenser 28, a second suitable direct-current source of energy, such as a second battery 101, or some rectified source of alternating energy for charging the small auxiliary condenser 28 at a predetermined rate, and a normally ineffective triggering or trip flash transformer 30. For definiteness, the larger flash condenser 26 may be referred to as a first condenser, and the small auxiliary condenser 28 as a second condenser.

A further such trip circuit is shown in Fig. 5 comprising a second such tube 140 (not shown), a second such capacitor 28 (not shown), and a second such transformer 30*a*. As these trip circuits are alike, only one of them is described in the specification of the said application, Serial No. 685,501.

The gaseous-discharge device 140 may be constituted of a mercury-vapor thyratron, a gas-filled hot-cathode thermionic tube or a grid-controlled cold-cathode aro-discharge tube or any other suitable discharge device. The transformer 30 may be of the high-ratio step-up or any other desired type, with a relatively low-impedance primary winding 36, and a secondary winding 29, shown connected between the cathode 4 and the external electrode 100. The before-mentioned starting-current path of the lamp 2, extending from the starting electrode 100 to the cathode 4, includes the inductance of the secondary winding 29. The trip circuit may contain other elements also; for example, in Fig. 1, the two impedances 31 and 33, and, in Fig. 2, the two impedances 31 and 133, all shown resistive, and connected into circuit with the source of potential 101.

The trip circuit may perform its function of initiating the discharge of the condenser 26 through its discharging circuit by converting the direct current of the second source of potential, such as the battery 101, into very sudden voltage pulses in the primary winding 36 of the flash-transformer 30. These, as will be described more fully presently, will be manifested as alternating current pulses in the secondary winding 29.

As the tube 140, like the lamp 2, may be a rectifier of the arc-like discharge type, conductive in one direction only, it serves also as an electric check valve. It is shown provided with at least three electrodes. Two of these are main or principal electrodes, namely, an anode or plate 52 and a cathode 48. The third is a control-grid electrode 50. These three electrodes correspond to the anode 6, the cathode 4 and the control electrode 100, respectively, of the flash lamp 2. The tube 140, like the tube 2, may be of the type having an abrupt characteristic. To energize the tube 140, a maximum predetermined potential may be impressed across it, between its two main or principal electrodes, without appreciable current flow between these electrodes, and a substantially constant potential difference may be impressed between the control electrode and one of the principal electrodes. The gas pressure of the tube 140 is such that the control electrode

50 loses control over a discharge already passing through the tube. The electric discharge of the second small condenser 28, as will be presently more fully explained, may be initiated to produce a current between the anode electrode 52 and the cathode electrode 48 by suitably controlling the third electrode 50.

The trip circuit is provided with a normally unenergized control input circuit and an output circuit. These will first be described in connection with the trip circuit of Figs. 1 and 2.

The output circuit of the trip circuit of Figs. 1 and 2, or of the thyratron 140, may be traced from the cathode 48, through the primary winding 36 of the flash transformer 30 and the small second condenser 28, to the anode 52. This output circuit of the trip circuit of Figs. 1 and 2 is connected to the lamp 2, since it includes the inductance of the primary winding 36 of the flash transformer 30, the secondary winding 29 of which has before been described as connected in the starting-current path of this lamp 2.

It has been stated that the small second condenser 28 in this output circuit of the trip circuit is charged from the battery 101. The impedance 133 of Fig. 2, like the impedance 33 of Fig. 1, is shown shunted across, or connected in parallel with, the small condenser 28. Each of these impedances 33 and 133 is also connected in parallel with the output circuit of the trip circuit, comprising not only the condenser 28, but also the cathode 48 and the anode 52 of the tube 140 and the primary winding 36 of the flash transformer 30, connected in series. The positive terminal of the battery 101 is connected to one terminal of the small second condenser 28 and one terminal of the resistor 33 or 133 and the negative terminal of the battery 101 is connected to the other terminal of the small condenser 28 and the other terminal of the resistor 33 or 133, through the resistor 31. Power is thus obtained for the thyratron 140 and for charging the small second condenser 28 in the output circuit of the trip circuit from the battery 101, in series with the resistor 31. The trip-circuit output circuit of Figs. 1 and 2, comprising the primary winding 36, the tube 140 and the small second condenser 28, in series, may therefore be regarded as obtaining its energy from this small condenser 28, after becoming charged from the battery 101. The battery 101 may, however, also be regarded as included within the output circuit of the trip circuit of Figs. 1 and 2. The resistor 31 may perform a function similar to that of the impedance 35 in the charging circuit of the condenser 26. The resistance of the resistor 31 may initially be so adjusted as to prevent self-operation of the trip circuit when the small second condenser 28 becomes charged.

The control input circuit of the trip circuit of Figs. 1 and 2 is the same as the input or grid circuit of the thyratron or other gaseous-discharge tube 140. In Fig. 2, this control input circuit may be traced from the cathode 48, through the primary winding 36, the portion of the impedance 31 to the left of a tap 151, and the secondary winding of a trip or grid transformer 64, the function of which will be explained presently, and through an impedance, shown as a resistor 142, to the control-grid electrode 50. The corresponding control input circuit of Fig. 1 contains a portion of the resistor 33, instead of the resistor 31, as in the system of Fig. 2, and it does not contain the secondary winding of

the trip or grid transformer 64. These differences will be discussed more fully presently.

The resistor 133 of Fig. 2 only is a bleeder resistor. The connection of this bleeder resistor 133 to the battery 101 before described is such as to allow a small current to flow in the resistor 31. A voltage becomes thereby established across the resistor 31 for impressing upon the control grid 50 of the thyratron 140 in these control input circuits a normal bias suitably negative with respect to the thyratron cathode 48. The control grid 50 is connected to the negative end of the resistor 31. As will hereinafter appear, advantage is taken of this normally negative voltage bias provided by the resistor 31 upon the control grid 50 to render the normally ineffective tube 140 effective at desired instants of time.

The resistance 133 is necessary to prevent the self-operation of the thyratron 140 when the condenser 28 becomes fully charged. The said resistance 133 (illustrated in Fig. 2 only) is made to have a large value, or is disconnected, when self-oscillations of the thyratron are desired as hereinafter more fully described.

The discharging circuit for the small condenser 28, in the trip circuits of Figs. 1 and 2, may therefore be traced from one terminal of the condenser 28, through the tube 140 and the primary winding 36, in series, to the other terminal of the small condenser 28. As soon as the normally non-conductive gaseous-discharge trigger tube 140 of the trip circuit is rendered conductive, therefore, the energy of the small condenser 28 is discharged through both the thyratron 140 and the primary winding 36, in series.

The conversion effected by the trip circuit of the direct current of the battery 101 into alternating-current pulses may be effected by this discharge of the small condenser 28 through the primary winding 36 of the flash transformer 30.

The condensers 26 and 28, however, may be charged through the impedance 35 from a common source of potential, as shown in Fig. 6.

The output circuit of the trip circuit or of the tube 140 of Fig. 3 may be traced from the cathode 48, through the small second condenser 28 and an impedance 33, shown as a resistor, connected in parallel, and through the primary winding 36, to the negative terminal of the battery 101. The output circuit is completed from the positive terminal of the battery 101, through a variable impedance 19, shown as a resistor, to the anode 52. As in the case of the trip circuits of Figs. 1 and 2, therefore, the battery 101 is included in the output circuit of the trip circuit of Fig. 3 also. An impedance 31, shown as a resistor, is connected in parallel between the cathode 48 and the anode 52. A by-pass condenser, not shown, is usually shunted across the battery 101 to by-pass the current surges that charge the condenser 28. This by-pass condenser may serve as the source of energy for the output circuit of the trip circuit of Fig. 3.

The inductance of the primary winding 36 in the starting-current path of the tube 2 is therefore connected in the output circuit of each of the trip circuits of Figs. 1, 2 and 3, between the cathode 48 and the plate or anode 52, in series with the small second condenser 28. The output circuit of each of the trip circuits of Figs. 1 and 2, however, as before described, is connected in shunt to the second battery 101. In the trip circuit of Fig. 3, on the other hand, the small second condenser 28, the primary winding 36 and the tube 140 are connected in series with the battery 101.

The control input circuit of the trip circuit of Fig. 3, or the input or grid circuit of its thyratron 140, may be traced from the cathode 48, through the small second condenser 28 and the impedance 33, in parallel, and from a tap 149 of the impedance 33, by way of an impedance, shown as a resistor 142, to the control-grid electrode 50. The negative bias upon the control grid 50 through this resistor is developed across the resistor 33 from the battery 101 in the circuit extending from the positive terminal of this battery 101, through the resistors 19, 31 and 33, and through the primary winding 36, to the negative terminal of the battery 101.

Because of the normally negative potential bias impressed on the control grid 50 in the control input circuit of the trip circuit of each of Figs. 1, 2 and 3, therefore, the output circuit is maintained normally open, to render the thyratron 140 normally non-conductive.

The control-grid electrode 50 may be caused to determine the exact instant when the normally non-conductive thyratron 140 shall become conductive. This control by the grid electrode 50 may be exercised by suitably modifying the potential difference between the negatively biased control grid 50 and one of the principal or main electrodes, as the cathode 48, to a predetermined critical value in order to energize the normally unenergized control input circuit of the trip circuit. This may be effected by subjecting the control grid 50 to a suitable stimulus, as will be described hereinafter. The normally open output circuit of each of the trip circuits of Figs. 1, 2 and 3 thereupon becomes closed or completed from the anode 52 to the cathode 48, in series with the low-impedance primary winding 36 and the small second condenser 28.

Referring to the trip circuits of Figs. 1, 2 and 3, the small second condenser 28 having meantime become charged, the energy thus stored in the condenser 28 becomes suddenly discharged through this output circuit of the trip circuit, between the anode 52 and the cathode 48. A sharp violent high-potential single electrical transient impulse becomes thus quickly, accurately and reliably impressed very suddenly, for a brief interval of time, upon the primary winding 36 of the thyratron trip circuit, at the exact instant desired, accompanied by a sudden surge of current therethrough.

The resulting high-potential trip surge across the terminals of the secondary winding 29 becomes conveyed, accurately and reliably, to impress a high-potential stimulus between the starting electrode 100 and the cathode 4 of the tube 2. In response to this sudden energization of the starting electrode 100, a triggering surge or pulse of current becomes thereupon suddenly initiated in the starting-current path between the control electrode 100 and the cathode electrode 4, resulting in the formation of a bright cathode spot of light on the surface of the mercury-pool cathode 4 at the junction between the mercury and the inner wall of the glass tube 2. A source of electrons becomes thereupon created upon the mercury cathode 4, in the vicinity of the cathode spot. These electrons ionize the normally un-ionized gas in the normally non-conductive lamp 2, to render it conductive. The flash condenser 26 having previously become charged to a suitable potential, it thereupon, at

the exact instant determined by the potential impulse upon the control grid 50, discharges quickly and violently to initiate current flow through the principal current path, including the gaseous medium of the lamp 2, between the cathode electrode 4 and the anode electrode 6. This violent electrical transient surge of current through the gaseous medium of the lamp 2 between the cathode 4 and the anode 6, thus produced in response to the potential stimulus impressed upon the thyratron grid 50, initiates, as before stated, a very brilliant intense quick sharp clear flash of light of high illumination intensity. At the instant of discharge, the current surge through the lamp 2 is very great. It may be over one thousand amperes.

Because of the low impedance of the mercury lamp 2, the duration of the flash discharge is short, of the order of microseconds, as determined by the size of the capacity 26, the dimensions of the lamp 2, its volt-ampere characteristics, its temperature, the impedance of the conductors 8 and 10 connecting the condenser 26 and the lamp 2, and other factors. The inductance of the conductors 8 and 10 is useful in extinguishing the arc, as it tends to make the discharge current oscillatory. Under some conditions, the duration of the flash is less than even one microsecond.

The arc through the lamp 2 is not maintained, but is promptly extinguished, because of the current-limiting action of the impedance 35. At the end of a predetermined interval of time, therefore, the current flow in the principal-current path becomes discontinued. The condenser 26 becomes thereupon again charged, in preparation for the next discharge.

The tube 140 therefore serves as a relay for accurately timing the starting of the mercury-arc tube 2. A timing impulse of only a few microamperes of current in the control input or grid circuit of the thyratron or other gaseous-discharge tube 140, to stimulate the grid 50, in the manner more fully described hereinafter, will effect the discharge of the small second condenser 28 through the output circuit, including the primary winding 36, at just the instant of time desired.

The timing voltage impulses in the control input circuit of the trip circuit for stimulating the control grid 50, in order to raise it to the predetermined critical value necessary to trip the thyratron 140, so as to render it conductive, may be obtained through the medium of an external signal. If the signal is reproduced at a predetermined rate repetitively, many times a second, at selected intervals determined by the predetermined rate, the resulting periodically produced flashes may be used, for example, for stroboscopic purposes; for the apparent speed of a moving object becomes thereby so effectively reduced, and the moving object moves so inappreciable a distance during the period of the flash, that it appears to be "stopped." Single signals, however, may also be used, as in flash photography.

In the trip circuit of Fig. 2, the external signal for rendering the tube 2 conductive is produced in the control input circuit with the aid of the trip or grid transformer 64 from an oscillator 62. The transformer 64 may be of the type that will yield a peaked secondary voltage. In response to the oscillation pulses of the oscillator 62, impulse charges become suddenly impressed intermittently upon the thyratron control grid 50 in order suitably to modify the potential thereof. It is in this manner that the potential of the control grid 50 intermittently becomes sufficiently critical with respect to the potential of the cathode 48 of the thyratron 140 to energize the normally unenergized control input circuit of the trip circuit, in order to render the thyratron 140 conductive.

Referring again to Fig. 2, the small second condenser 28 discharges suddenly through the output circuit of the trip circuit in response to each of these impulses in order to establish suddenly the before-mentioned violent high-potential single electrical transient pulse in this output circuit. A high-potential gradient becomes thus established in the output circuit in response to each such discharge of the small second condenser 28.

Corresponding energizing pulses are thereupon produced intermittently in the transformer 30 to effect sudden transient energizations of the normally unenergized starting electrode 100, intermittently to render the lamp 2 suddenly conductive at times determined by the discharges of the small second condenser 28. At each such discharge of the small condenser 28, the normally ineffective transformer 30 becomes thus suddenly effective to subject the starting electrode 100 of the tube 2 to a relatively high potential. This, as before stated, renders the tube 2 suddenly conductive, in order that a current impulse may be obtained through the gaseous medium of the tube 2, by the discharge of the condenser 26, between the cathode 4 and the anode 6, to produce the flash. This result is effected without the aid of any switches in the high-voltage circuit, merely by having the oscillator 62 supply periodically the signal charges to the grid 50.

The duration of each such sudden discharge of the condenser 28 through the output circuit constituted of the small second condenser 28 produced by the before-described impulse upon the control grid 50 is short compared to the times between successive discharges of the small second condenser 28. This is because the control grid 50 is normally maintained at a potential such as to render the thyratron 140 normally non-conductive during times long compared to the duration of the pulse in the trip output circuit. Because of the suddenness of the operation, the thyratron or other tube 140 becomes effective with corresponding suddenness to render the lamp 2 suddenly conductive.

In the trip circuits of each of Figs. 1 and 2, an energizing pulse is impressed suddenly upon the primary winding 36 of the transformer 30 by a discharging surge of current from the source of energy constituted of the small second condenser 28. A corresponding sudden energizing pulse may equally well be produced in the primary winding 36 by a charging surge of current, during the charging of the small condenser 28, however, as occurs in the trip circuit of Fig. 3. In this case, the pulse is produced suddenly from the battery 101 or the before-mentioned by-pass condenser, not shown. In the trip circuits of each of Figs. 1, 2 and 3, the control electrode 50 loses control over the thyratron 140 upon the initiation by the condenser 28 of the sudden current impulse in the output circuit.

In the trip circuit of Fig. 2, when the tube 140 is rendered conductive, in response to a voltage pulse upon the control grid 50, from the transformer 64, the potential of the cathode 48 is raised

to nearly that of the anode 52. This results in a charging surge of current into the small second condenser 28 and, at the same time, through the output circuit, including the primary winding 36. During the ensuing discharge, a sudden very strong negative bias becomes reestablished upon the grid 50.

The surge in the control input circuit may, of course, be brought about in other ways also, as by the use of electrical transients in transformers, or by impulses from photo-electric cells, amplifiers, etc. In the trip circuit of Fig. 5, as a further example, the signal for controlling the flashes of light is supplied to the grid 50 through the closing of a switch contactor 32. Upon the closing of the switch contactor 32, at any time after the condenser 28 has become charged, the grid 50 of the thyratron 140 will receive a potential stimulus of the same nature as already described, to effect the discharge of the small second condenser 28 into the primary winding 36.

The input circuit of the trip circuit or the input or grid circuit of the thyratron 140 of Fig. 5 may be traced from the cathode 48, through various impedances, shown as resistors, a portion of the impedance 33, and an impedance 142, also shown as resistors, to the control-grid electrode 50. The tripping is performed by a control series circuit between the control grid 50 and the anode 52. In this control series circuit, the control grid 50 is shown connected to one side of the switch 32 through a trip condenser 59, which may be as small as 0.00025 microfarad, in parallel with a leak resistor 143. The other side of the switch 32 is connected to the anode 52 through the primary winding 36. The control grid 50 is connected also to a negatively biased portion of the resistor 33, in series with the resistor 142. The resistance of the resistor 142 limits any current that may tend to flow when the grid 50 becomes positive, or when there is any ionization in the tube. Especially in variable-speed stroboscopes, the adjustment of a suitable impedance, such as the impedance 19 of Fig. 3, may be employed to vary the intensity of the starting voltage applied to the starting-grid electrode 100.

The output circuit of the trip circuit or of the thyratron 140 of Fig. 5 may be traced from the cathode 48, through an impedance, shown as a resistor, the small condenser 28 and the primary winding 36 to the anode 52.

In the trip circuits of Fig. 5, the closing of the switch contactor 32 may be controlled in any desired manner, manually or automatically. An example of an automatic control, effected through the medium of a periodically movable member, is described in Letters Patent 2,181,879, issued December 5, 1939, reissued as Letters Patent 22,123, June 23, 1942, and Letters Patent 22,260, February 2, 1943. The switch 32 may be very small, since it need carry only very small currents.

The invention of the said application, Serial No. 685,501, therefore, makes it possible to operate the system without any switches or other moving parts, except, in some cases, as with the aid of the very small switch contactor 32, for causing the thyratron or other gas-discharge tube 140 to function.

By varying the frequency of the oscillator 62 or the speed of operation of the switch 32 of the illustrated trip circuits, it is possible to vary the number of times per second that the external signal is applied to the control grid 50 to control the thyratron or other gaseous-discharge device 140 to render it conductive. The predetermined rate at which the signal is applied may thus be varied to vary the selected intervals of flashing.

The rate of flashing may be controlled, however, by suitably varying the frequency in other ways also. The voltage-impulse stimulus may, for example, be transmitted from the control circuit to the output circuit of the trip circuit, and from this output circuit to the lamp 2, to produce the flashes of light, without any outside aid, such as the oscillator 62 of Fig. 2 or the switch contactor of Fig. 5, purely through self-oscillation of the system. The tripping surges in the grid circuit may be supplied by transformer or capacity coupling as commonly used in the art, or in any other desired manner.

The control may, for example, be effected by varying the impedance 31 or 33, as for example, by connecting the control grid 50 to various taps on the resistance 33 or 31, as illustrated at 146 in Fig. 1, and at 149, in Fig. 3, and also in Figs. 4, 5 and 6, to cause the thyratron 140 to oscillate as a relaxation oscillator.

The adjustment of either tap may thus control the flashing rate of the condenser 28 and, therefore, the frequency of the high-voltage surges that become impressed upon the starting electrode 100.

The impedances 31 and 33 need not, however, be resistive. If, for example, the impedance 31 is reactive, or if there are other circuit conditions such that the voltage of the grid 50 may exceed the critical starting potential, the thyratron circuit may, under certain conditions, generate its own oscillations at a frequency determined by the circuit constants and the characteristics of the tube 140. The thyratron or other gaseous-discharge device 140 will under these circumstances also oscillate as a self-excited relaxation oscillator. The electrical impulses for stimulating the thyratron control grid 50 in order to initiate the discharges of the condenser 26 through the lamp 2 at the desired selected intervals may thus be produced at a controlled rate determined by the adjustment of this self-excited relaxation oscillator.

The self-excited relaxation-oscillator thyratron circuit described in the preceding paragraphs as initiating discharge of the condenser 26 at selected intervals is sometimes termed a self-excited static inverter. This inverter produces electrical impulses at a controlled rate determined by its adjustment. If an external signal is used to trip the thyratron (such as from the grid transformer 64 and the oscillator 62 illustrated in Fig. 2), the circuit is sometimes called a driven static inverter.

The manner of connecting the grid for self-oscillation depends upon the characteristics of the particular thyratron that is used. For thyratrons with a negative control characteristic (which start when the grid voltage is negative), circuits of the type shown in Figs. 2, 3, 5 and 6 may be used. For thyratrons with a positive control characteristic (which start when the grid voltage is positive) circuits of the types shown in Figs. 1, 5 and 6 may be used. Thyratrons, furthermore, especially the inverter types that have a short deionization time, require a certain amount of grid current in order to conduct. Often a positive voltage is required on the grid of a negative-control thyratron to supply the required grid current through the grid resistor 142. The grid resistor 142, if varied, will vary the self-oscillation rate, if grid currents are necessary for starting.

The flashes of light from the tube are controlled by the oscillations of the inverter, and adjustment of the frequency may be made by changing the value of the charging resistance.

The thyratron does not conduct current when there are no impulses in the grid circuit, except when used for self-oscillation, as described. The oscillator 62, the switch 32 and the self-excited oscillations are alternative arrangements, all fully equivalent for the purpose of producing the above-described stimulus upon the thyratron control grid 50 for causing the discharge of the flash condenser 26 through the lamp 2. In all cases, the light flashes will occur accurately and reliably, at just the desired selected intervals, in response to the discharge of the condenser 26 through the tube 2, once during each cycle of the oscillations of the oscillator 62, or of the self-oscillations, or once corresponding to each closing of the very small switch contactor 32. In all cases, the voltage impulses will thus occur at the instant that the current flow through the tube 140 is conveyed, through the transformer 30, to the flash-producing apparatus.

The electrical parameters of the discharging circuit of the condenser 26 are such that, if the lamp 2 were conductive in both directions between the principal electrodes 4 and 6, the circuit would be oscillatory. This oscillatory tendency is useful, however, since it assists in preventing a continuous flow of current through the lamp 2 from the direct-current power supply, such as the battery 102. The condenser 26 is charged with a potential of an opposite polarity after a surge of current flows through the tube 2. A negative voltage is thus put on the anode 6, which helps to deionize the tube.

As the thyratron 140 is a rectifier, the current in the circuit comprising the condenser 28 and the transformer 30 cannot oscillate, although there is a tendency to do so.

The resistance 31 may be made to have a high value; or it may be open circuited, if self-oscillations are desired. Variation of the tap 146 on the resistor 33 (Fig. 1), or other variation of the value of the resistor 33, will vary the frequency of the self-excited static inverter circuit just described. A variable impedance 33, included as an element in the inverter circuit (Fig. 3), may be connected with the tube 140 in the charging circuit of the second condenser 28 for varying the impulse rate by controlling the current flowing through the tube 140 and, therefore, the intervals between condenser discharges. Similar remarks apply to variation of the tap 149 of the resistor 33 of Fig. 3.

The grid 50 is, in this case, shown connected, through the resistor 142, to the tap 149 of the resistor 33, connected in parallel to the condenser 28, thus providing a variable impedance shunted across the second condenser 28. In Figs. 1 and 2, on the other hand, as previously stated, the second condenser 28 is shown shunted across the main electrodes 48 and 52 of the gaseous-discharge device 140. In all cases, the condenser 28 is caused to discharge through the gaseous-conductor device 140 by varying the potential of the grid electrode 50.

Figs. 4, 5 and 6 illustrate circuits that are efficient for charging the discharge condenser 26. In Figs. 4 and 5, the charging circuit consists of the impedance 35 in series with a rectifier tube, shown at 7 in Fig. 4 and at 107 in Fig. 5. The tubes 7 and 107 flash as they charge the condenser 26 and a second flash is obtained when a second tube 2 short-circuits the condenser 26.

A circuit breaker 120 (Fig. 4) is useful for protection of high-efficiency charging circuits, since large currents are apt to flow if the tube 2 does not operate properly. The "holdover" current through the tube 2 is limited by the regulation of the power supply 102, the resistance of impedance 35, and the effective resistance of the tube 2.

The operation of the remainder of the circuit of Fig. 4 is the same as has been described in the discussion of Fig. 2, except that the grid of the tube 7 is shown connected to the cathode. This thyratron 140 forms an inverter of the self-driven type in conjunction with the other component parts of the circuit. The flashes of light from the tube 2 are controlled by the oscillation of the inverter, and adjustment of the frequency is made by changing the value of the charging resistance 31.

In Fig. 5, the rectifier tube 107, as before stated, is illustrated as of the same type as the flash tube 2. Control is obtained by a surge into the transformer 30a from a thyratron inverter, either self-oscillatory or externally driven, as has been described in connection with the Figs. 1, 2 and 3.

Fig. 6 illustrates a circuit arrangement that is particularly useful for obtaining flashes of light that are multiples of the line frequency.

The anode of a further thermionic or gaseous-discharge half-wave rectifier tube 21 is connected to a tap 161 of the transformer secondary winding 147. The cathode of the further rectifier 21 is connected in series with an adjustable impedance 31, shown as a resistor, to charge the second condenser 28. The connection of the condenser 28 to the cathode of the rectifier 21 through the resistor 31 is similar to that of the cathode of the rectifier 20 through the impedance 35 to the condenser 26. The rectifier 21 thus charges the condenser 28 from the same alternating source 144 of voltage as the condenser 26, but through the impedance 31.

The cathode of the rectifier 21 is shown connected also through the impedance 31, shown as a resistor, to the anode 52 of the thyratron 140, similarly to the connection of the cathode of the rectifier 20 to the anode 6 of the lamp 2. The grid 50 of the thyratron 140 is connected through the resistor 142 to that end of the further secondary winding 160 of the transformer 148 that is negative during the half-cycle while the condensers 26 and 28 are being charged.

While the grid 50 is negative, the thyratron is ineffective and, therefore, the condensers 28 and 26 are permitted to accumulate a charge. On the succeeding half-cycle, the grid 50 swings positive and trips the thyratron 140 which, in turn, causes the main condenser 26 to discharge through the mercury-arc tube 2, as has been previously explained.

The variable resistance 31 or 142 makes it possible to arrange the circuit so that flashes every other cycle or every third cycle or other submultiple can be selected by adjustment. The thyratron 140 for this purpose is one with a positive control characteristic or one that requires positive grid current to start.

The control input circuit of the trip circuit of Fig. 6 may be traced from the cathode 48, through the primary winding 36, by way of the conductor 8, through the portion 160 of the secondary winding 147, and through an impedance 142, shown as a resistor, to the control-grid electrode 50. The

output circuit of the trip circuit may be traced from the cathode 48, through the primary winding 36, and through the small auxiliary condenser 28, to the anode 52. The small condenser 28 is charged by a charging circuit extending from the terminal 161 of an intermediate portion of the secondary winding 147, through the half-wave rectifier 21 and an impedance 31, shown as a resistor, and through the small condenser 28, to the other terminal of the intermediate portion of the secondary winding 147. The half-wave rectifier 21 converts the alternating current supplied by the intermediate portion of the secondary winding 147 into direct current for this output circuit.

The circuit of Fig. 6 constitutes the subject matter of a divisional application, Serial No. 688,405, filed August 5, 1946.

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. In combination with apparatus for producing electrical-energy flashes of the type in which a condenser is periodically discharged through a gaseous-conductor lamp, means for initiating discharge of the condenser at selected intervals consisting of a relaxation oscillator for producing electrical impulses at a controlled rate, said relaxation oscillator comprising a gaseous-discharge device connected in circuit with a source of potential and with means for varying the impulse rate comprising a variable impedance, means for conveying such impulses to the flash-producing apparatus, and means for adjusting the quantity of light in the electrical-energy flashes.

2. Light-flashing apparatus having, in combination, a light-flashing tube, a condenser connected to the tube to discharge through the tube to produce a flash of light, means for connecting the condenser to a source of energy, capacitive means in series with the condenser and the tube, and means for adjusting the capacitive means to adjust the quantity of light contained in the flash of light.

3. Light-flashing apparatus having, in combination, a light-flashing tube, a condenser connected to the tube to discharge through the tube to produce a flash of light, means for connecting the condenser to a source of energy, transformer means separate from the source of energy in series with the condenser and the tube and means for adjusting the transformer means to adjust the quantity of light contained in the flash of light.

4. In combination with apparatus for producing electrical-energy flashes of light of the type in which a condenser is periodically discharged through a gaseous-conductor lamp, means for initiating discharge of the condenser at selected intervals consisting of a relaxation oscillator for producing electrical impulses at a controlled rate, said relaxation oscillator comprising a gaseous-discharge device in series circuit with a source of potential and with a second condenser, means for varying the impulse rate comprising a variable impedance shunted across said second condenser, means for conveying such impulses to the flash-producing apparatus, and means for adjusting the quantity of light contained in the flashes of light.

5. In combination with apparatus for producing electrical-energy flashes of the type in which a condenser is periodically discharged through a gaseous-conductor lamp, means for initiating discharge of the condenser at selected intervals consisting of a relaxation oscillator for producing electrical impulses at a controlled rate, said relaxation oscillator comprising a gaseous-discharge device connected in circuit with a source of potential, a second condenser shunted across the gaseous-discharge device, means for varying the impulse rate comprising a variable impedance connected in the charging circuit of the second condenser, means for conveying such impulses to the flash-producing apparatus, and means for adjusting the quantity of light in the electrical-energy flashes.

6. In combination with apparatus for producing electrical-energy light flashes of the type in which a condenser is periodically discharged through a gaseous-conductor lamp, means for initiating discharge of the condenser at selected intervals comprising a discharge device connected in circuit with a source of potential and with means for varying the impulse rate, means for conveying such impulses to the flash-producing apparatus, and means for adjusting the quantity of light in the light flashes.

7. In combination with apparatus for producing electrical-energy light flashes of the type in which a condenser is periodically discharged through a gaseous-conductor lamp, means for initiating discharge of the condenser at selected intervals comprising a gaseous-discharge device connected in circuit with a source of potential, a second condenser shunted across the gaseous-discharge device, means for varying the impulse rate, means for conveying such impulses to the flash-producing apparatus, and means for adjusting the quantity of light in the light flashes.

8. A stroboscope having, in combination, a normally non - conductive gaseous - conductor lamp for producing light flashes of substantial illumination intensity having two electrodes, means for connecting the electrodes to a source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to produce a current impulse from the source through the lamp between the electrodes when the lamp is non-conductive but sufficient to produce a current impulse from the source through the lamp between the electrodes to produce a light flash when the lamp is conductive, a trip circuit comprising a discharge device, means for connecting the discharge device to the lamp, means for impressing impulses at a predetermined rate upon the discharge device, means controlled by the discharge device in response to the impulses for producing sudden violent electrical transient impulses at the predetermined rate, and means for transmitted the transient impulses to the lamp to render the lamp suddenly conductive at selected intervals in accordance with the predetermined rate in order to produce current impulses from the source through the lamp between the electrodes at the selected intervals to produce light flashes of substantial illumination intensity at the selected intervals, and means for adjusting the quantity of light in the light flashes.

9. A stroboscope having, in combination, a normally non - conductive gaseous - conductor lamp for producing light flashes of substantial illumination intensity having two electrodes, means for connecting the electrodes to a source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to

produce a current impulse from the source through the lamp between the electrodes when the lamp is non-conductive but sufficient to produce a current impulse from the source through the lamp between the electrodes to produce a light flash when the lamp is conductive, a trip circuit comprising a condenser, means for charging the condenser, a discharge device connected between the condenser and the lamp, means for impressing impulses at a predetermined rate upon the discharge device, and means controlled by the discharge device in response to the impulses for causing the condenser to produce sudden violent electrical transient impulses at the predetermined rate for transmission through the discharge device to the lamp to render the lamp suddenly conductive at selected intervals in accordance with the predetermined rate in order to produce current impulses from the source through the lamp between the electrodes at the selected intervals to produce light flashes of substantial illumination intensity at the selected intervals, and means for adjusting the quantity of light in the light flashes.

10. A stroboscope having, in combination, a normally non - conductive gaseous - conductor lamp for producing light flashes of substantial illumination intensity having two electrodes, means for connecting the electrodes to a first source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to produce a current impulse from the source through the lamp between the electrodes when the lamp is non-conductive but sufficient to produce a current impulse from the source through the lamp between the electrodes to produce a light flash when the lamp is conductive, a trip circuit comprising a discharge device having two principal electrodes and a control electrode, an output circuit connected to the principal electrodes provided with a second source of energy, means for normally maintaining the control electrode at a predetermined potential to maintain the discharge device normally non-conductive, means for modifying the predetermined potential at a predetermined rate to render the discharge device conductive at the predetermined rate in order that the second source of energy may produce suddent violent electrical transient impulses in the output circuit at the predetermined rate, means whereby the normally maintaining means maintains the control electrode at the predetermined potential during times long compared to the duration of the transient impulses in the output circuit, and means for connecting the output circuit to the lamp to transmit the transient impulses to the lamp to render the lamp suddenly conductive at selected intervals in accordance with the predetermined rate in order to produce current impulses from the first source through the lamp between the electrodes at the selected intervals to produce light flashes of substantial illumination intensity at the selected intervals, and means for adjusting the quantity of light in the light flashes.

11. A stroboscope having, in combination, a normally non - conductive gaseous - conductor lamp for producing light flashes of substantial illumination intensity having two electrodes, a first condenser, means for connecting the first condenser to the electrodes, means for charging the first condenser to a voltage of magnitude insufficient to effect a discharge of the first condenser through the lamp between the electrodes when the lamp is non-conductive but sufficient to effect a discharge of the first condenser through the lamp between the electrodes to produce a light flash when the lamp is conductive, a trip circuit comprising a second condenser, means for charging the second condenser, a discharge device connected between the second condenser and the lamp, means for impressing impulses at a predetermined rate upon the discharge device, and means controlled by the discharge device in response to the impulses for causing the second condenser to induce sudden violent electrical transient impulses at the predetermined rate for transmission through the discharge device to the lamp to render the lamp suddenly conductive at selected intervals in accordance with the predetermined rate in order to effect discharges of the first condenser through the lamp between the electrodes at the selected intervals to produce light flashes of substantial illumination intensity at the selected intervals, and means for adjusting the quantity of light in the light flashes.

12. A light-flash producer having, in combination, a normally non-conductive gaseous-conductor lamp for producing light flashes of substantial illumination intensity having two electrodes, means for connecting the electrodes to a source of energy to impress between the electrodes from the source of voltage of magnitude insufficient to produce a current impulse from the source through the lamp between the electrodes when the lamp is non-conductive but sufficient to produce a current impulse from the source through the lamp between the electrodes to produce a light flash when the lamp is conductive, a trip circuit comprising a normally non-conductive discharge device, means for connecting the discharge device to the lamp, means for impressing an impulse upon the discharge device to render the discharge device conductive, means controlled by the discharge device upon the discharge device becoming conductive for producing a sudden violent electrical transient impulse, and means for transmitting the transient impulse to the lamp to render the lamp suddenly conductive in order to produce a current impulse from the source through the lamp between the electrodes to produce a light flash of substantial illumination intensity, and means for adjusting the quantity of light in the light flash.

13. A light-flash producer having, in combination, a normally non-conductive gaseous-conductor lamp for producing light flashes of substantial illumination intensity having two electrodes, means for connecting the electrodes to a first source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to produce a current impulse from the source through the lamp between the electrodes when the lamp is non-conductive but sufficient to produce a current impulse from the source through the lamp between the electrodes to produce a light flash when the lamp is conductive, a trip circuit comprising a discharge device having two principal electrodes and a control electrode, an output circuit connected to the principal electrodes provided with a condenser and a second source of energy for charging the condenser, a transformer having a primary winding connected in the output circuit and a secondary winding, means for normally maintaining the control electrode at a predetermined potential to maintain the discharge device normally non-conductive, means for modifying the prede-

termined potential to render the discharge device conductive in order that the condenser may produce a sudden current impulse in the output circuit to impress a sudden violent electrical transient impulse upon the primary winding, means whereby the normally maintaining means maintains the control electrode at the predetermined potential during a time long compared to the duration of the transient impulse, and means for connecting the secondary winding to the lamp to transmit the transient impulse in the primary winding through the secondary winding to the lamp to render the lamp suddenly conductive in order to produce a current impulse from the first source through the lamp between the electrodes to produce a light flash of substantial illumination intensity, and means for adjusting the quantity of light in the light flash.

14. A light-flash producer having, in combination, a normally non-conductive gaseous-conductor lamp for producing light flashes of substantial illumination intensity having two electrodes, means for connecting the electrodes to a first source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to produce a current impulse from the source through the lamp between the electrodes when the lamp is non-conductive but sufficient to produce a current impulse from the source through the lamp between the electrodes to produce a light flash when the lamp is conductive, a trip circuit comprising a gaseous-discharge device having two principal electrodes and a control electrode, an output circuit connected to the principal electrodes provided with a condenser and a second source of energy for charging the condenser, means for normally maintaining the control electrode at a predetermined potential to maintain the discharge device normally non-conductive, means for modifying the predetermined potential to render the discharge device conductive in order that the condenser may produce a sudden violent electrical transient impulse in the output circuit, means whereby the normally maintaining means maintains the control electrode at the predetermined potential during a time long compared to the duration of the transient impulse, and means for connecting the output circuit to the lamp to transmit the transient impulse to the lamp to render the lamp suddenly conductive in order to produce a current impulse from the first source through the lamp between the electrodes of the lamp to produce a light flash of substantial illumination intensity, the gas pressure of the discharge device being such that the control electrode loses control over the discharge device upon the initiation of the production by the condenser of the sudden current impulse in the output circuit, and means for adjusting the quantity of light in the light flash.

15. A light-flash producer having, in combination, a normally non-conductive gaseous-conductor lamp for producing light flashes of substantial illumination intensity having two electrodes, a condenser, means for connecting the condenser to the electrodes, means for charging the condenser to a voltage of magnitude insufficient to effect a discharge of the condenser through the lamp between the electrodes when the lamp is non-conductive but sufficient to effect a discharge of the condenser through the lamp between the electrodes to produce a light flash when the lamp is conductive, a trip circuit comprising a discharge device, means for connecting the discharge device to the lamp, means for impressing an impulse upon the discharge device, means controlled by the discharge device in response to the impulse for producing a sudden violent electrical transient impulse, and means for transmitting the transient impulse to the lamp to render the lamp suddenly conductive in order to effect a discharge of the condenser through the lamp between the electrodes to produce a light flash of substantial illumination intensity, and means for adjusting the quantity of light in the light flash.

16. A light-flash producer having, in combination, a normally non-conductive gaseous-conductor lamp for producing light flashes of substantial illumination intensity having two electrodes, a first condenser, means for connecting the first condenser to the electrodes, means for charging the first condenser to a voltage of magnitude insufficient to effect a discharge of the first condenser through the lamp between the electrodes when the lamp is non-conductive but sufficient to effect a discharge of the first condenser through the lamp between the electrodes to produce a light flash when the lamp is conductive, a trip circuit comprising a second condenser, means for charging the second condenser, a discharge device connected between the second condenser and the lamp, means for impressing an impulse upon the discharge device, and means controlled by the discharge device in response to the impulse for causing the second condenser to produce a sudden violent electrical transient impulse for transmission through the discharge device to the lamp to render the lamp suddenly conductive in order to effect a discharge of the first condenser through the lamp between the electrodes to produce a light flash of substantial illumination intensity, and means for adjusting the quantity of light in the light flash.

HAROLD E. EDGERTON.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,410,702	Meyer	Mar. 28, 1922
1,608,268	Found et al.	Nov. 23, 1926
1,640,966	Seguin et al.	Aug. 30, 1927
1,695,719	Rudenberg	Dec. 18, 1928
1,799,993	Staege	Apr. 7, 1931
2,004,270	Davey	June 11, 1935
2,006,737	Gessford	July 2, 1935

FOREIGN PATENTS

Number	Country	Date
120,621	Switzerland	June 1, 1927

OTHER REFERENCES

"Hot Cathode Thyratrons" by A. W. Hull, paper #491, pp. 3–23.

Reprint from G. E. Review (pp. 213–223, Apr. 1929, and pp 390–399 of the July issue).

Certificate of Correction

Patent No. 2,478,904 August 16, 1949

HAROLD E. EDGERTON

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 16, line 59, for the word "transmitted" read *transmitting*;

and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 21st day of March, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.