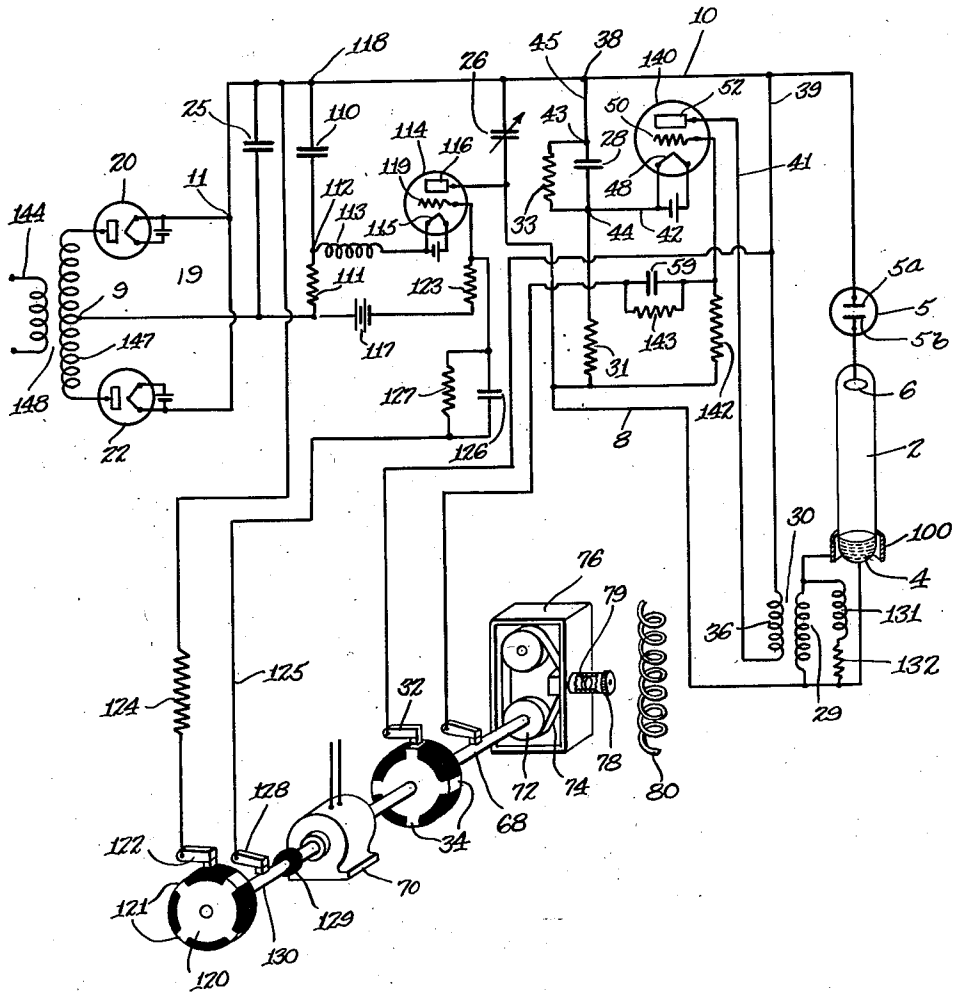
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FLASH-PRODUCING DEVICE

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FLASH-PRODUCING DEVICE

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1

The present invention, though having fields of more general usefulness in electric systems, is particularly related to electric-energy flash-producing or other pulse-producing systems in which the discharge of a condenser is employed for such purposes as to produce a single light flash or a single electric-energy pulse or a repetition of light flashes or electric-energy pulses of short duration and high intensity. This application is a continuation-in-part of application Serial No. 714,978, filed March 10, 1934, which matured, on January 9, 1940, into Letters Patent 2,186,013.

In application, Serial No. 685,501, filed August 16, 1933, there is disclosed a new and improved electric system for producing strong and intense substantially uniform pulses of electric energy by discharging a condenser quickly, reliably and accurately at high frequency through a gaseous-conductor device. 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.

An object of the present invention is to provide a new and improved electric system of the above-described character for producing light flashes or other pulses of electric energy.

Another object is to provide a new and improved system of the above-described character for charging the condenser.

Another object is to provide a new and improved system of the above-described character in which the condenser is disconnected from its charging source of energy upon the completion of the charging thereof and prior to its discharge.

In the said application, Serial No. 685,501, the source of the light flashes is disclosed as a three-electrode gaseous-conductor device. A further object of the present invention, on the other hand, is to provide a new and improved system of the above-described character in which a three-electrode gaseous-conductor device serves rather as a control for a load, disclosed specifically as a two-electrode gaseous-conductor flash-producing device.

A further object of my invention is to provide an improved flash-producing device in which the source of light is obtained from successive surges of current flowing through a circuit including a luminescent-discharge device which is adapted to high-speed operation.

Another object of my invention is to provide a flash-producing device in which the source of light is obtained from successive discharges

2

of a condenser through a luminescent-discharge device or devices and in which the condenser is disconnected from the charging source prior to discharge.

Further objects of my invention will become apparent as the description proceeds and the features of novelty which characterize my invention will be pointed out in the claims annexed to and forming a part of this specification.

The invention will now be described in connection with the accompanying drawings, the single figure of which is a diagrammatic view of a motion-picture camera embodying my invention.

As the energy per flash through a gaseous-discharge tube increases, or as the rate of flashing increases, the tube increases in temperature. This increase in temperature is accompanied by a relatively greater intensity of light, by a slower deionization time of the tube after each flash, and by the requirement of a higher operating voltage. The slower deionization time of the tube limits the recharging time of the condenser and thus lengthens the necessary interval between flashes. This is one of the limits to the speed at which the camera may be operated.

To overcome the difficulty of slow deionization and, at the same time, to benefit from the increased intensity of light obtained from a hot tube or other discharge device having a slow deionization time, I propose to connect in series with this tube a tube proportioned so that it shall remain cool at the required operating speed and to control the flow of current through the hot tube by means of the cool tube.

In the form of my invention illustrated, the light to expose the film is obtained from a gaseous-electric-discharge device 5 in series with a luminescent gaseous-electric-discharge device, such as a tube 2. The gaseous-conductor tube 2 may be of the normally non-conductive rectifier type described in the said Letters Patent and in Letters Patent 2,181,879, of December 5, 1939, reissued as Letters Patent 22,123, June 23, 1942, and Letters Patent 22,260, February 2, 1943, and is proportioned so that it shall remain cool and have a rapid deionization time. Reference may be made to the said Letters Patent for details. As also described in the said Letters Patent, it is provided with two internal main or principal electrodes 4 and 6 in a glass-tube envelope. The internal electrode 4 is shown in the form of a liquid pool of mercury, used for a cathode, and the internal electrode 6 serves as the anode or plate. The tube 2 is described in the said Letters

Patent as of the low-impedance mercury-arc gaseous-conductor type, in which a positive-column discharge may pass between the anode electrode 6 and the cathode electrode 4. The pressure of the mercury or other gas or vapor in tubes of this nature is normally of such value as to render the tube 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 of the tube 2 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 Letters Patent as an external metal-band condenser electrode, situated around the glass of the envelope of the tube 2, outside the mercury pool 4, opposite to the meniscus of the mercury. Other types of control-grid or starting electrode, including electrodes of the internal type, may also be employed.

The discharge device 5 has electrodes 5*a* and 5*b*, but needs no control electrode, since the current through it is controlled by the tube 2. The discharge device 5 may be any gaseous-discharge device, such as electrodes spaced in air, or within an envelope. If the electrodes are within an envelope, one of the electrodes may be of mercury, or both may be of metal. The medium confined within the envelope may be a gas or vapor and I find that the gas or vapor pressure within the envelope may be substantial, even of the order of magnitude of atmospheric pressure, without affecting very satisfactory operation of the device. The deionization time of a discharge device such as shown at 5 is relatively slow; but, since it is in series with the tube 2, which deionizes very rapidly, the deionization time of the device 5 is not important, as the deionization of the tube 2 interrupts the current.

The invention is not, of course, restricted to use with the two-electrode gaseous-conductor lamp 5. This two-electrode lamp 5 is quite efficient for the production of light flashes, but the invention is equally applicable to the production of other electric-energy pulses than light. The lamp 5 is therefore merely representative of a suitable load device that may be employed in accordance with the present invention under the control of the three-electrode gaseous-conductor device 2.

Direct-current voltage is shown as derived from any desired conventional source of alternating energy of suitable voltage and frequency, through a transformer 148. The primary winding 144 of the transformer 148 is shown connected to the alternating-current source, and the secondary winding 147 to the anodes of two thermionic or gaseous-discharge half-wave rectifier-tube units 20 and 22 of a common conventional type of full-wave rectifier-and-filter arrangement 19. The positive terminal 11 of the rectifier source of energy is represented by the cathodes of the rectifiers 20 and 22, and the negative terminal 9 is disposed at an intermediate tap of the secondary winding 147 of the transformer 148. An impedance 111, shown resistive, and a reservoir condenser 110, are shown connected in series between the terminals 11 and 9 across a filter condenser 25, which may constitute part of the conventional source of direct current. A continuous supply of direct-current energy is thus continuously maintained between the positive terminal 118 and the negative terminal 112 of the reservoir condenser 110. A lead conductor 10 is connected to the positive terminal 118 of the reservoir condenser 110 and a lead conductor 8 is connected to the negative terminal 112 at times when a normally non-conductive thyratron or other suitable discharge device 114 is rendered conductive.

A main discharge capacitor or condenser 26 is connected to the terminals 112 and 118 of this reservoir-condenser source 110 of direct-current potential in order normally to charge it with energy at a predetermined rate to the full potential or greater than the full potential of this source 110. According to the embodiment of the invention herein illustrated and described, the condenser 26 is connected to the source of direct-current potential 110 in parallel with the gaseous-conductor device 2 and the load 5, connected in series. The electrodes 4 and 6 of the discharge device 2 and the electrodes 5*a* and 5*b* of the load 5 are therefore connected in series to the two terminals 112 and 118 of the condenser source 110 of energy at the same time that energy is supplied to the condenser 26 from the source 110 of direct current. The positive terminal of the condenser 26 is connected to the positive terminal 118 of the reservoir condenser 110 by the load conductor 10, and the negative terminal of the condenser 26 is connected to the negative terminal 112 of the reservoir condenser 110 at times when the normally non-conductive tube 114 is rendered conductive. The usual voltage to which the condenser 26 becomes thus charged when the tube 114 is conductive is from 200 to 2,000 volts.

The discharging circuit for the condenser 26 is shown extending from the positive terminal of the condenser 26, by way of the lead conductor 10, and through the gaseous medium of the load 5, between the electrodes 5*a* and 5*b*; from the electrode 5*b*, by way of a conductor, to the anode electrode 6; then through the gaseous medium of the gaseous-conductor tube 2 to the cathode electrode 4; and finally from the cathode electrode 4, by way of the lead conductor 8, to the negative terminal of the condenser 26. The cathode 4 and the anode 6 of the gaseous-conductor device 2 are thus connected by the lead conductors 8 and 10 to the condenser 26 in series with the load 5. Because of the direct metallic-wire connection, the condenser 26 is enabled to discharge with relative rapidity through the gaseous-conductor tube 2 between the anode electrode 6 and the cathode electrode 4 when the gaseous-conductor tube 2 becomes conductive.

The discharge of the condenser 26 in this discharging circuit, however, can be effected in one direction only. This is because, as explained in the said Letters Patent, the discharge device 2 is conductive in one direction only, since it has rectifier characteristics.

With this arrangement, I prefer to have the electrical parameters of this series condenser-discharging circuit, including the condenser 26 and the inductance of the lead conductors 8 and 10, such that, if the discharge device 2 were substantially equally conductive in both directions between the principal electrodes 4 and 6, this condenser-discharging circuit would be oscillatory. For brevity, therefore, I shall hereinafter use this term "oscillatory" to describe this condenser-discharging circuit.

As the tube 2 will not conduct a reverse current, the current flow through the tube ceases when the oscillatory discharge current from the condenser

26 becomes zero. At this time, as the condenser 26 is charged in the reverse direction, it can not discharge through the tube 2 and the discharge device 5 until charged in the normal direction, because of the rectifier action of the tube 2. When the discharge is oscillatory, the duration of the surge of current through the discharge devices is equal to the duration of the first half-cycle of the discharge. This period is independent of the energy stored in the condenser and depends only on the constants of the circuits. It is much shorter than the interval of time between successive flashes.

The reason why the duration of the surge of current is so much shorter than the interval of time between successive surges of current will appear more fully hereinafter. It will appear that the closing of the contact members 121, 122, by effecting the closing of the charging circuit for the condenser 26, determines the moment when the condenser 26 commences to charge; and that the closing of the contact members 32, 34 determines the moment when the condenser 26 commences to discharge. The commutator 120 travels through a very small angle during the time that the flash takes place, else the pictures taken would become blurred, instead of very sharp and very distinct.

Although the discharge or gaseous-conductor device 2 is illustrated and described as a rectifier, however, it will be obvious that the invention is not limited thereto, but that the invention may be practised with the aid of any other means having similar rectifier characteristics. Any discharge device or gaseous-conductor or other means may be employed in accordance with the present invention that has rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under the before-described predetermined conditions of the reverse voltage applied to it by reason of the oscillatory nature of the condenser-discharging circuit. In particular, the lamp or other load 5 and the discharge device 2 may together constitute a normally non-conductive gaseous-conductor means having such rectifier characteristics. The electrodes of this gaseous-conductor means 2 and 5 may be considered to be the main or principal electrode 4 of the gaseous-conductor device 2, the electrode 5*a* of the gaseous-conductor device 5, and the third or control electrode 100 of the gaseous-conductor device 2.

In order to allow still further time for deionization, I provide an arrangement for charging the condenser 26, in which the condenser is charged just before the desired time of the flash, and is then disconnected from the charging source before the time of the flash. With this arrangement, there is no chance for current to flow through the discharge devices until the charging source of voltage is again connected to the condenser 26 to charge the condenser. For instance, if pictures are to be taken at the rate of 5,000 per second, or one picture every 200 microseconds, and the duration of the flash is one microsecond, it is possible to allow 100 microseconds or more for deionization of the tube 2, and the discharge device 5 need never be completely deionized. The only requirement is that the before-described series discharging circuit of the condenser 26, which includes the tube 2 and the discharge device 5, must be able to stand, without breakdown, the voltage across the condenser 26 when the condenser 26 is again being charged.

The charging circuit for the condenser 26 is shown extending from the positive terminal 118 of the reservoir condenser 110, by way of the conductor 10, to the corresponding positive terminal of the condenser 26; and from the negative terminal 112 of the reservoir condenser 110, through a current-limiting reactive charging impedance 113, constituted of a wire conductor comprising a combination of resistance and inductance, and the normally non-conductive thyratron or other suitable gaseous-conductor device 114, to the negative terminal of the condenser 26. The current-limiting charging impedance 113 is thus series-conducted in the charging circuit of the condenser 26, between the condenser 26 and its charging source 110 of direct current.

It is desired not to produce a pulse in the load 5 except during the discharge of the condenser 26. The design of the above-described condenser-charging circuit aids toward the attainment of this end by not producing a substantial or, indeed, any pulse in the load 5 during the charging of the condenser 26.

The thyratron tube 114 is shown provided with a cathode 115, an anode 116 and a control-grid electrode 119. The grid 119 of the tube 114 is connected to the negative end of the resistance 111 through a grid-protecting resistance 123 and is, therefore, given a negative bias with respect to the cathode 115 when current flows through the resistor. A battery 117 may be used to increase the negative bias of the grid 119, so as to prevent the tube 114 from operating until the closing of the contact members 121 and 122. The tube 114, as already stated, is, therefore, normally non-conductive and the condenser 110 is, therefore, normally disconnected from the condenser 26. In order to render the tube 114 conductive, the grid 119 is connected to the positive side of the source of direct current by a circuit which includes a resistance 124, contact members 121 and 122, a conducting shaft 130, a contact member 128, a conductor 125, and a trip condenser 126. The function of the resistance 124 is to limit the peak current. At the first instant of closing of the contact members 121 and 122, the condenser 126 has no charge and the resistances 124 and 123 act as a voltage divider, so that the grid 119 is at a positive potential sufficient to cause the tube 114 to become conductive. The next instant, however, the condenser 126 becomes charged, which draws a charging current through the grid-protecting resistor 123. As soon as the condenser 126 becomes charged, the voltage in the grid 110 drops to a low value. The potential of the grid 119 becomes less negative with respect to the cathode and, therefore, causes the tube 114 to become non-conductive as soon as the plate current becomes zero. The time that the tube 114 remains conductive is not dependent upon the time that the contact members 121 and 122 remain closed. The drawing of the current through the resistor 123 results in the potential of the grid 119 becoming momentarily highly positive with respect to the cathode 115, resulting in operation of the tube 114. The condenser 126 discharges through a shunt leak resistance 127 when the contact members 121 and 122 are open.

Upon the normally non-conductive thyratron 114 becoming conductive, in response to the closing of the contact members 121 and 122, it performs the function of a switch for closing the charging circuit of the condenser 26 through the current-limiting inductance 113, in order to permit of recharging the condenser 26 from the res-

ervoir condenser 110. A difference of potential becomes thus established between the cathode 4 and the anode 6 during the charging of the condenser 26.

The condenser 26 is therefore normally charged to a voltage of unvarying polarity and of magnitude insufficient to effect a discharge of the condenser 26 through the gaseous-conductor tube 2 between the electrodes 4 and 6 when the gaseous-conductor tube 2 is non-conductive, though sufficient to effect a discharge of the condenser 26 through the tube 2 between the electrodes 4 and 6 when the tube 2 has broken down to become conductive.

After becoming thus charged, the condenser 26, as will presently be more fully explained, may be discharged through the gaseous medium of the tube 2, between the anode 6 and the cathode 4, and through the load 5, between the electrodes 5a and 5b, in the before-described discharging circuit of the condenser 26. The discharge current thus obtained from the condenser source 26 of energy produces an electric-energy pulse through the gaseous-conductor tube 2 and, therefore, through the load 5 also. This results in the production of a light flash through the device 2 and, therefore, through the lamp 5 also. The impedance 113 should be small enough to permit recharging of the condenser 26 with energy from the direct-current source 110 in time for the next light flash or energy pulse.

Like the gaseous-conductor device 2, the gaseous-conductor device 114 has rectifier characteristics. The electrical parameters of the above-traced condenser-charging circuit for the condenser 26, including the impedance 113 and the condenser 26 in series with the condenser-charging source 110 of energy, are such that, if the electron-discharge device 114 were conductive in both directions between the cathode 115 and the anode 116, this condenser-charging circuit would be oscillatory. For brevity, therefore, I shall hereinafter use this term "oscillatory" to describe this condenser-charging circuit.

Because of the nature of this series condenser-charging circuit for the condenser 26, furthermore, the voltage rise across the condenser 26, the gaseous-discharge device 5 and the gaseous-discharge tube 2 in the above-traced discharging circuit for the condenser 26 is retarded. The inductance of the impedance 113 prevents a sudden initial rush of current through the tube 114, or through any switch that may be used in place of the tube 114.

Resulting also from the fact that this series condenser-charging circuit for the condenser 26 is oscillatory, for reasons similar to those discussed above in connection with the oscillatory nature of the condenser-discharging circuit, the plate current of the gaseous-conductor device 114 is brought to zero, which enables its control-grid electrode 119 to regain control. It will also be apparent, for reasons similar to those hereinbefore discussed, that any discharge device 114 having rectifier characteristics may be employed in accordance with the present invention that does not conduct an appreciable current in the reverse direction under the influence of the reverse voltage applied to it by reason of the oscillatory nature of this condenser-charging circuit.

In an oscillatory circuit of this type, the condenser 26 is charged to a higher potential than the supply of direct current at the time when the current becomes zero. The efficiency of charging the condenser is also increased. As energy is

transferred from the condenser 110 to the condenser 26, the potential of the cathode 115 becomes more positive relative to the terminal 9 of the source of direct current. The grid 119, therefore, becomes more negative with respect to the cathode 115, and the deionization of the tube 114 is assisted. When the tube 114 is deionized, the condenser 26 is effectively disconnected from the condenser 110. There is a tendency for the current to oscillate, but it will flow in only one direction.

The voltage to which the condenser 26 is charged, as before stated, must be insufficient to cause the tube 2 to break down and become conductive without the starting pulse of potential. In order to cause the tube 2 to become conductive, at the desired intervals, I provide a trip circuit for energizing the electrode 100. The trip circuit is shown comprising a normally non-conductive or ineffective gaseous-discharge trigger-tube device 140, a small auxiliary capacitor or condenser 28, and a normally ineffective triggering or trip flash transformer 30. For definiteness, the larger condenser 26 may be referred to as a first condenser, and the small auxiliary condenser 28 as a second condenser. The small second condenser 28 is shown provided with a positive terminal 43 and a negative terminal 44.

The gaseous-discharge device 140, like the gaseous-conductor device 114, may comprise a mercury-vapor thyratron, a gas-filled hot-cathode thermionic tube, a grid-controlled cold-cathode arc-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 tube 2, extending from the starting electrode 100 to the cathode 4, includes the inductance of the secondary winding 29.

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 source of potential 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 gaseous-conductor devices 114 and 140, like the gaseous-conductor device 2, may be rectifiers of the arc-like discharge type, having an abrupt characteristic, and conductive in one direction only, they may serve also as electric check valves. They are each shown provided with at least three electrodes. Two of the electrodes of the tube 140 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 gaseous-conductor device 2, or the anode 116, the cathode 115 and the control electrode 119, respectively, of the gaseous-conductor device 114. As is the case also with the gaseous-conductor device 114, the maximum predetermined potential that may be established between the two main or principal electrodes 48 and 52 of the gaseous-conductor device 140, without appreciable current flow therebetween, may be controlled by controlling the potential difference between the control electrode and one of the main or

principal electrodes. As with the gaseous-conductor devices 2 and 114, the gas pressure of the gaseous-conductor device 140 is such that the control electrode 50 loses control over a discharge already passing through the gaseous-conductor device 140.

The conversion effected by the auxiliary or trip circuit of the direct current of the reservoir condenser 110 into alternating-current pulses may be effected by discharging the small condenser 28 between the anode electrode 52 and the cathode electrode 48 in order to produce a current through the primary winding 36 of the flash transformer 30. This discharge of the small second condenser 28, as will presently be more fully explained, may be initiated by suitably controlling the third electrode 50 of the thyratron or other discharge device 140.

The condenser 28, which provides the initiating impulse in the auxiliary circuit, is charged, through a resistance 31, from any suitable source of direct current, which may be the source of direct-current supply for the condenser 26. The auxiliary or trip circuit is provided with a normally unenergized series control circuit, an input circuit and an output circuit. The input circuit of the trip circuit, or the input or grid circuit of the thyratron 140, may be traced from the cathode 48, by way of a conductor 42, to the negative terminal 44 of the small condenser 28, and through resistors 31 and 142, to the control-grid electrode 50. The connections of the output circuit of the trip circuit, or of the thyratron 140, include the conductor 42, leading from the terminal 44 of condenser 28, to the cathode 48 of the electron-discharge device 140; a conductor 41, leading from the anode 52 of the electron-discharge device 140 to the primary winding 36; and the conductors 39, 10 and 45 leading from the primary winding 36 to the other terminal 43 of the condenser 28.

This output circuit of the trip circuit thus comprises not only the small second condenser 28, but also the cathode 48 and the anode 52 of the gaseous-conductor tube 140 and the primary winding 36 of the flash transformer 30, connected in series. It is connected to the gaseous-conductor tube 2 through the transformer 30.

An impedance 33, shown as a bleeder resistor, is connected to the terminals 43 and 44 of the small second condenser 28. It is therefore shunted across, or connected in parallel with, the small second condenser 28, and therefore also with the output circuit of the trip circuit.

The positive terminal 118 of the source 110 of direct-current voltage is connected to the positive terminal 43 of the small second condenser 28 and of the bleeder resistor 33, and the negative terminal 112 of this voltage source 110 is connected to the negative terminal 44 of the small condenser 28 and of the bleeder resistor 33, through the resistor 31, at times when the tube 114 is energized. Power is thus obtained both for the thyratron 140 and for charging the small second condenser 28, in the output circuit of the trip circuit, from the reservoir condenser 110, in series with the resistor 31. This trip-circuit output circuit may therefore be regarded as obtaining its energy from this small second condenser 28, after becoming charged from the reservoir condenser 110. The reservoir condenser 110 may, however, also be regarded as included within the output circuit of the trip circuit.

In addition to its above-described function of providing a bias for the control-grid electrode 50, therefore, the resistor 31 may perform also, in the charging circuit of the small second condenser 28, a function similar to that of the impedance 113 in the charging circuit of the condenser 26.

The current flowing through the bleeder resistance 33 causes a voltage drop through the resistance 31, which is negative with respect to the cathode 48; and, since the grid 50 is connected to the negative end of the resistance 31, through a resistance 142, the grid 50 is normally negative with respect to the cathode 48. The presence of the bleeder 33 permits more current to pass through the resistance 31, and the function of the resistor 142 is similar to that of the resistor 123. The tube 140 is, therefore, normally nonconductive, as before stated, preventing discharge of the condenser 28 through the tube 140. The bias normally developed across the resistor 111 may be large enough to prevent the gaseous-conductor device 114 from operating except when the contact members 121 and 122 are closed.

To render the discharge device 140 conductive, a switch, having a stationary brush or contact member 32 and movable contact members 34, is closed to connect the grid 50 to the positive side of the source of direct current, at the conductor 10, and by way of the conductor 39. A small trip condenser 59 is arranged in the circuit between the conductor 10 or the anode 52 and the grid 50 and is quickly charged after the contact members 32 and 34 are closed. The condenser 59 performs the same function for controlling the thyratron 140 that the condenser 126 performs for controlling the thyratron 114. After the condenser 59 is charged, the grid 50 again becomes negative with respect to the cathode 48, and remains negative regardless of the time that the contact members 32 and 34 remain closed. Only a single impulse is obtained at each closing of the contact members 32 and 34. A resistor 143, in shunt to the condenser 59, performs a function similar to that of the resistor 127 for the condenser 126. Each resistor takes the charge from its corresponding condenser when the contact members 121, 122 or 32, 34, respectively, become open.

Even after current flow has ceased in the primary winding 36, however, an oscillatory current may continue to flow in the secondary winding 29. The voltages thus applied to the electrode 100 by the oscillations of the secondary winding 29 may be sufficient to cause the tube 2 to become conductive after the condenser 26 has become only partly recharged, or to delay the deionization of the tube 2 until the condenser 26 has become partly recharged. This would result in further discharges of the condenser 26 through the tube 2 even in the absence of the application of a further triggering impulse upon the thyratron 140, with the consequent production of spurious flashes. It might even result in continuous conduction through the tube 2. In order to prevent this from occurring, the triggering impulse applied to the electrode 100 should be of duration short compared to the desired intervals between the discharges of the condenser 26 through the tube 2 and, therefore, between the flashes.

According to the embodiment of the invention that is herein illustrated and described, I attain this result by preventing the current in the secondary winding 29 from becoming oscillatory. To this end, I have connected a resistance 132 and an inductance 131 across the secondary winding 29, of values such that the surge of current through the winding 29 is substantially damped. Other arrangements for providing a damped sec-

ondary winding may also be used, such as varying the constants of the winding 29 itself. By the use of the damped transformer for impressing the starting voltage on the grid 100, it is possible to use a surge from a low-voltage source, such as the condenser 28, in the primary winding 36 and to obtain a single, corresponding surge in the secondary winding 29 of sufficient voltage to cause the tube 2 to become conductive. An auxiliary electrode in the tube 2, when connected to the secondary, has been found to be useful for damping out the oscillations in the secondary.

The tripping is performed by energizing the normally unenergized control series circuit of the trip circuit between the control grid 50 and the anode 52. This normally unenergized control series circuit is energized by means of a signal for controlling the flashes of light or the electric-energy pulses that suitably modifies 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. The signal is produced, as above described, by subjecting the control grid 50 to a suitable potential stimulus through closing the switch contactor 32 at any time after the small second condenser 28 has become charged. The normally open output circuit of the trip circuit 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.

The small second condenser 28 thereupon discharges through the output circuit of the trip circuit, from the positive terminal 43 of the small second condenser 28, by way of the conductor 45, to a terminal 38, by way of the conductors 10 and 39, through the primary winding 36 and the gaseous-conductor tube 140, between the anode 52 and the cathode 48, in series, and, by way of the conductor 42, to the negative terminal 44 of the small second condenser 28. The discharging surge of current thus produced from the source of energy constituted of the small second condenser 28 results in impressing very suddenly, for a brief interval of time, at the exact instant desired, a sharp violent high-potential single electrical transient impulse upon the primary winding 36 of the transformer 30. In response to each such discharge of the small condenser 28, therefore, the normally ineffective transformer 30 becomes thus suddenly effective, and a high-potential gradient becomes established in the output circuit of the trip circuit.

The control grid 50 is thus caused to determine the exact instant when the normally non-conductive thyratron 140 shall become conductive, and this it does quickly, accurately and reliably. The control electrode 50 loses control over the thyratron 140, however, upon the initiation by the condenser 28 of the sudden current impulses in the output circuit.

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.

The effect of this quickly applied, high voltage is to produce a source of electrons upon the mercury cathode 4, rendering the tube 2 conductive. The main discharge condenser 26, therefore, suddenly, quickly and violently, at the exact instant determined by the potential impulse, under the control of the control-grid electrode 50, discharges its energy through the tubes 2 and 5 in response to the closing of the contact members 32, 34.

Part of this energy is transformed into useful light. The amount of energy discharged through the tube 2 by the circuit is so considerable that the flash of light produced by the resulting arc is very brilliant, intense, quick, sharp, clear and 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 gaseous-conductor devices 2 and 5, the duration of each such sudden discharge of the condenser 26 and of the resulting flash or other pulse of electric energy is short compared to the times between successive discharges of the condenser 26 and 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 discharge of the condenser 26 and 28. Because of the suddenness of the operation, the thyratron or other tube 140 becomes effective with corresponding suddenness to render the gaseous-conductor device 2 suddenly conductive. The duration is of the order of microseconds. Under some conditions, the duration of the flash is less than even one microsecond.

This time duration is short enough to obtain sharp, clear photographs of moving objects and for taking a series of photographs upon a continuously moving film without blur. The duration of the flash of light from the tube 5 is also so short (ten microseconds or less) that no appreciable blurring of the image on the film occurs, even at high, film speeds. The intensity of the light is such that adequate exposures are obtained with one flash of light from the tube 5. The duration of the flash depends upon a number of factors, among which are the capacity of the condenser 26 and the energy stored therein, the impedance of the leads 8 and 10, and the dimensions and operating temperature of the tube 2.

By designing the gaseous-conductor tube 2 so that it shall have a low impedance relative to that of the load 5, most of the discharge energy will be dissipated in that load 5. The tube 5, on the other hand, is generally designed for the most effective light emission, and to have a high impedance relative to that of the gaseous-conductor tube 2.

By varying the speed of operation of the switch 32 of the illustrated trip circuit, 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 present invention, 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.

The illustrated camera 76 can be used for taking pictures of rapidly moving objects at very high speeds. A motor 70 drives a drum 72 which continuously advances a band of film 74 within the camera 76 behind a lens 79 provided with a shutter 78 that operates automatically to prevent

double exposure of the film. The motor also rotates a commutator of which the contact members 34 are segments and on which bears the before-mentioned stationary brush or contact member 32. The contact members 32 and 34 control the timing of the light flashes; as explained above, each time that the contact members 32 and 34 close, a single flash of light from the tube 2 is obtained. The commutator is usually driven so that a separate flash is obtained each time that the film advances one frame distance, in order that the pictures shall be properly framed for subsequent projection. For other uses, the flashing rate is accurately determined by a separate commutator, run at a known speed. Tripping may also be arranged from an electrical oscillator or other sources of alternating current.

The movable contact members 121 are preferably the segments of a commutator 120, which is mounted on a shaft 130, driven by the motor 70. The contact members 121 are all connected to the shaft 130, and the brush 128, which bears on the shaft 130, completes the circuit from the contact members 121 to the conductor 125. An insulating member 129 insulates the shaft 130 from the rest of the motor 70. The commutator 120 is placed so that the contact members 121 and 122 shall have become closed and opened before the contact members 32 and 34 close to cause the condenser 26 to discharge through the circuit including the tube 2 and the discharge device 5, in the manner described above. Due to the simplification of the camera, because of the elimination of the intermittent motion of the film, the number of pictures per second may be very great, 1000 or more. This type of photography is very useful in the study of certain high-speed phenomena in engineering research investigations, such as a rapidly moving valve spring 80.

In the operation of the camera, just prior to the closing of the contact members 32 and 34, the condenser 26 is charged and is disconnected from the full-wave rectifier, the condenser 28 is charged, the tubes 140 and 2 are non-conductive, and the film 74 is about to be accurately framed behind the lens 79.

As soon as the film 74 is accurately framed behind the lens 79, the contact members 32 and 34 are closed, connecting the grid 50 to the positive conductor 10 and rendering the tube 140 conductive. The energy in the condenser 28 immediately discharges, causing a surge of current to flow through the primary winding 36 and a corresponding surge to be magnetically induced in the secondary winding 29. The surge of voltage in the secondary winding 29 causes the tube 2 to become conductive, and the condenser 26 discharges through the oscillatory circuit including the tube 2 and the discharge device 5, producing a flash of light. At the end of the first half-cycle of the oscillation, current flow from the condenser 26 ceases and since, at this instant, the condenser 26 is charged in the reverse direction, no further current flow is possible. As the secondary winding 29 is damped, only a single oscillation appears in the winding 29 at each closing of contact members 32 and 34.

As before explained, as soon as the condenser 28 discharges, the cathode 48 becomes more positive and, since the condenser 59 has, by this time, become charged, the grid 50 returns to its negative potential. The negative bias of the grid 50 is sufficient to cause the tube 140 to become non-conductive, and further surges from the condenser 28 are not possible until the contact members 32 and 34 are again closed.

The condenser 26 remains disconnected from its condenser-charging source 110 a predetermined length of time after the discharge of the condenser 26 and until after the tube 2 has become deionized. The charging circuit for the condenser 26 is therefore ineffective, in order to prevent charging of the condenser 26, during that predetermined time. At some time after the tube 2 has become deionized, the contact members 121 and 122 become closed, causing the tube 114 to become conductive and, thereby, causing the condenser 26 to become charged from the condenser 110. After the condenser 26 is charged, the tube 114 becomes non-conductive and the condenser 26 becomes effectively isolated from the charging source. The condenser 28 has been charged through the resistance 31 which, as before stated, is intermittently connected to the full-wave rectifier. The system is therefore now ready to deliver another surge of current to the tube 2 and the discharge device 5. This surge will not occur until the contact members 121 and 122 have become opened and the contact members 32 and 34 have again become closed.

The electrical control circuits illustrated and described herein make it possible to control accurately the exact instant of the light flash by means of a very small amount of power. If the contact brush 32 and commutator contact member 34 are small and are very accurately constructed, as shown diagrammatically, the circuit will be tripped at exactly the right instant to "frame" the picture on the moving film. The importance of accurate flashing of the intermittent-light source will be realized when the magnification of the picture on the screen during projection is calculated. The brushes and the commutator would become pitted in case any appreciable current were required to flow in them, resulting eventually in inaccurate timing of the flashes of light. In the circuits illustrated and described herein, the current requirements are very small and consist of brief pulses occurring at the instant of contact.

The control tube 2, together with the circuit for exciting its external starting grid, is useful for many other applications than the one shown in this patent application. The circuit is particularly adapted for the production of one or more short-duration high-energy pulses of electrical energy in any desired load impedance, such as the gaseous-conductor tube 5. These pulses may be very accurately controlled by a very small amount of energy, and this may be produced at a very rapid rate.

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. A flash-producing device comprising a luminescent-discharge device; a condenser; a discharge circuit including said condenser and said luminescent-discharge device; an impedance; a rectifier tube; means for charging said condenser including a circuit having a source of direct current, said impedance and the said rectifier tube; and means for causing said condenser to discharge suddenly through said luminescent-discharge device at predetermined intervals of time.

2. A flash-producing device comprising a lumi-

nescent-discharge device, a condenser, a discharge circuit including said condenser and said luminescent-discharge device, means including a circuit having a source of direct current for charging said condenser and then disconnecting the condenser from the source of direct current, means for subsequently causing said condenser to discharge through said luminescent-discharge device, and means for rendering the second-named circuit successively effective and ineffective to charge the condenser periodically, thereby to permit the condenser to discharge periodically through said luminescent-discharge device.

3. A flash-producing device comprising a luminescent-discharge device, a condenser, a discharge circuit including said condenser and said luminescent-discharge device, an electron-discharge device having a control grid, a charging circuit for said condenser including a source of energy and said electron-discharge device, means including said control grid for causing said condenser to be charged and then to be disconnected from said source of energy, and means for causing said condenser to discharge through said luminescent-discharge device.

4. A flash-producing device comprising a luminescent-discharge device, a condenser, a discharge circuit including said condenser and said luminescent-discharge device, a grid-controlled discharge device, a charging circuit for said condenser including a source of energy and the grid-controlled discharge device, means including an auxiliary circuit connected to said charging circuit for causing said condenser to be charged, and means for subsequently causing said condenser to discharge through said luminescent-discharge device.

5. A flash-producing device comprising a mercury-pool tube, a condenser, a discharge circuit including said condenser and said tube, an electron-discharge device having a control grid, a charging circuit for said condenser including a source of energy and said electron-discharge device, means including said control grid for causing said condenser to be charged and then to be disconnected from said source of energy, and means for causing said condenser to discharge through said tube.

6. A flash-producing device comprising a luminescent-discharge device, a condenser, a discharge circuit including said condenser and said luminescent-discharge device, means including a source of energy for charging said condenser, means for causing said condenser to discharge through said luminescent-discharge device at successive intervals, and means for successively disconnecting said condenser from said source of energy during and subsequent to said discharge.

7. A flash-producing device comprising a circuit including a condenser and a mercury-pool tube having a starting electrode, a transformer having a primary winding and a damped secondary winding connected to said starting electrode, means for charging said condenser, and means for causing said condenser to discharge through said tube, said last-named means including means for causing a surge of current to flow through the primary winding of the transformer.

8. A flash-producing device comprising a circuit including a condenser and a gaseous-electric-discharge device having a control grid, a transformer having a primary winding and a damped secondary winding connected to said control grid, means for charging said condenser, and means for causing said condenser to discharge through said discharge device, said last-named means including means for causing a surge of current to flow through the primary winding of the transformer.

9. A flash-producing device comprising a luminescent-discharge device; a condenser; a discharge circuit including said condenser and said luminescent-discharge device; an impedance; a thyratron tube, means for charging said condenser including a circuit having a source of direct current, said impedance and said thyratron tube; and means for causing said condenser to discharge suddenly through said luminescent-discharge device at predetermined intervals of time.

10. A flash-producing device comprising a luminescent-discharge device, a condenser, a discharge circuit including said condenser and said luminescent-discharge device, means for charging said condenser, means for causing said condenser to discharge suddenly through said luminescent-discharge device at predetermined intervals of time, and means for thereupon rendering the condenser-charging means ineffective.

11. A flash-producing device comprising a luminescent-discharge device, a condenser, a discharge circuit including said condenser and said luminescent-discharge device, a second discharge device, a charging circuit for said condenser including a source of direct current, the second discharge device being disposed between the source of direct current and the luminescent-discharge device, means including an auxiliary circuit connected to said charging circuit for causing said condenser to be charged, and means for subsequently causing said condenser to discharge through said luminescent-discharge device.

12. A flash-producing device comprising a luminescent-discharge device having a control electrode, a condenser, a discharge circuit including said condenser and said luminscent-discharge device, an electron-discharge device having a control grid, a charging circuit for said condenser including a source of energy and said electron-discharge device, a transformer having a primary winding and a secondary winding connected to the control electrode, and means for causing said condenser to discharge through said luminescent-discharge device, said means including means for causing a surge of current to flow through the primary winding of the transformer.

13. A flash-producing device comprising a circuit including a condenser and a gaseous-discharge device having a starting electrode, a transformer having a primary winding and a substantially damped secondary winding connected to said starting electrode, and means for causing current to travel through said device, said means including means for causing a surge of current to flow through the primary winding of the transformer.

14. A flash-producing device comprising a gaseous-electric-discharge device having a control grid, a transformer having a primary winding and a secondary winding connected to said control grid, an impedance connected in parallel with the secondary winding to damp it, and means for causing current to travel through said discharge device, said means including means for causing a surge of current to flow through the primary winding of the transformer.

15. In apparatus for producing electrical energy flashes, a condenser, a direct-current source

of potential for charging the condenser, means for charging the condenser to a predetermined potential higher than the potential of the energy source, said means comprising an inductance and an electric check valve connected in series circuit with the energy source and with the condenser, and means for discharging the condenser at selected intervals.

16. In flash producing apparatus, a gaseous-conductor device having at least three electrodes of the type in which an electric discharge between two main electrodes may be initiated by changing the potential of the third electrode, a condenser shunted across the main electrodes, means for charging said condenser comprising a source of direct current, an inductance and an electric check valve connected in series, and means for varying the potential of said third electrode to cause said condenser to discharge through said device.

17. In flash producing apparatus, a trigger tube flashing device, a condenser shunted across two electrodes of said device, means for charging the condenser comprising a source of direct current and an electric check valve and an inductance forming with the condenser an oscillating circuit, and means for applying a discharge initiating stimulus to said trigger tube to cause said condenser to discharge through said device.

18. In apparatus for producing substantially uniform electric energy flashes, a condenser, means for charging the condenser, comprising a source of direct current and a conductor having resistance and inductance of such magnitude relative to the capacity of the condenser that the charging circuit is an oscillating circuit, such means being adapted to develop a maximum condenser voltage not substantially higher than the condenser voltage which exists at the instant immediately preceding the discharge of the condenser and means for discharging the condenser at selected intervals.

19. In flash producing apparatus, a gaseous conductor device having at least three electrodes of the type in which an electric discharge between two main electrodes may be initiated by changing the potential of the third electrode, a condenser shunted across the main electrodes, means for charging said condenser comprising an oscillating circuit which includes a source of current, an inductance and an electric check valve connected in series with said condenser, and means for varying the potential of said third electrode to cause said condenser to discharge through said device.

20. An electric system comprising a gaseous-electric-discharge device having a control grid, a transformer having a primary winding and a secondary winding connected to said control grid, an impedance connected in parallel with the secondary winding to damp it, and means for causing current to travel through said discharge device, said means including means for causing a surge of current to flow through the primary winding of the transformer.

21. A light-flash producer having, in combination, a luminescent-discharge lamp having an anode and a cathode, a condenser, means connecting the condenser to the anode and the cathode to provide a discharge circuit including the condenser and the lamp, an inductance, a gas-filled rectifier, a charging circuit for the condenser including a source of direct current, the inductance and the rectifier connected in series, and means for impressing an impulse to cause the condenser to discharge suddenly into the discharge circuit and between the anode and the cathode through the lamp, thereby to produce a flash of light.

22. A light-flash producer having, in combination, a luminescent-discharge lamp having an anode and a cathode, a condenser, means connecting the condenser to the anode and the cathode to provide a discharge circuit including the condenser and the lamp, a rectifier having a control electrode, a charging circuit for the condenser including the rectifier, means controlled by the control electrode for controlling the time at which the condenser commences to charge, and means for causing the condenser to discharge into the discharge circuit and between the anode and the cathode through the lamp.

23. A light-flash producer having, in combination, a luminescent-discharge lamp having an anode and a cathode, a source of direct-current energy, a condenser, a rectifier, a charging circuit for the condenser including the source and the rectifier, and means for producing successive sudden discharges of the condenser to produce between the anode and the cathode through the lamp successive sudden surges of energy, each energy surge of duration short compared to the time between the successive condenser discharges, thereby to produce in the lamp successive well defined light flashes of high intensity.

24. A light-flash producer having, in combination, a luminescent-discharge lamp having an anode and a cathode, a condenser, a rectifier, a charging circuit for the condenser including the rectifier, a second rectifier, and means controlled by the second rectifier for producing successive sudden discharges of the condenser to produce between the anode and the cathode through the lamp successive sudden surges of energy, each energy surge of duration short compared to the time between the successive condenser discharges, thereby to produce in the lamp successive well defined light flashes of high intensity.

25. A light-flash producer having, in combination, a normally non-conducting luminescent-discharge lamp, a condenser, an inductance, an electric check valve, means for charging the condenser comprising the inductance and the electric check valve connected in series circuit with a source of direct-current energy and with the condenser, a discharge circuit into which the condenser may be discharged, the discharge circuit including the condenser and the lamp, and means for producing in the discharge circuit at selected intervals successive sudden discharges of the condenser each of duration short compared to the time between successive discharges.

26. In flash producing apparatus, a gaseous conductor device having at least three electrodes of the type in which an electric discharge between two main electrodes may be initiated by changing the potential of the third electrode, a condenser shunted across the main electrodes, means for charging said condenser comprising a source of current, an inductance and an electric check valve connected in series, and means for varying the potential of said third electrode to cause said condenser to discharge through said device.

27. An electric system comprising a circuit including a condenser and a mercury-pool tube having a starting electrode, a transformer having a primary winding and a substantially damped secondary winding connected to said starting electrode, means for charging said condenser, and means for causing said condenser to discharge

through said tube, said last-named means including means for causing a single surge of current to flow through the primary winding of the transformer.

28. An electric system comprising a circuit including a condenser and a gaseous-electric-discharge device having a control grid, a transformer having a primary winding and a substantially damped secondary winding connected to said control grid, means for charging said condenser, and means for causing said condenser to discharge through said discharge device, said last-named means including means for causing a single surge of current to flow through the primary winding of the transformer.

29. An electric system comprising a circuit including a condenser and a gaseous-discharge device having a starting electrode, a transformer having a primary winding and a substantially damped secondary winding connected to said starting electrode, and means for causing current to travel through said device, said means including means for causing a single surge of current to flow through the primary winding of the transformer.

30. In apparatus of the character described, a condenser, a direct-current source of potential for charging the condenser, means for charging the condenser to a predetermined potential higher than the potential of the energy source, said means comprising an inductance and an electric check valve connected in series circuit with the energy source and with the condenser, and means for discharging the condenser at selected intervals.

31. In apparatus of the character described, a trigger-tube device, a condenser shunted across two electrodes of said trigger-tube device, a circuit for charging the condenser comprising a source of current, an electric check valve, an inductance and the condenser, the circuit exclusive of the electric check valve being oscillatory, and means for applying a discharge-initiating stimulus to said trigger-tube device to cause said condenser to discharge through said trigger-tube device.

32. In apparatus of the character described, a gaseous-conductor device having at least three electrodes of the type in which an electric discharge between two main electrodes may be initiated by changing the potential of the third electrode, a condenser shunted across the main electrodes, means for charging said condenser comprising a circuit which includes a source of current, an inductance and an electric check valve connected in series with said condenser, the circuit exclusive of the electric check valve being oscillatory, and means for varying the potential of said third electrode to cause said condenser to discharge through said device.

33. In combination with apparatus having a cathode and an anode and adapted for excitation by electrical impulses, means for exciting such apparatus comprising a condenser connected to the cathode and the anode, a source of direct-current energy for charging the condenser, means connected in series circuit with the energy source and with the condenser for charging the condenser comprising an electric check valve and an indutance, and means for discharging the condenser at selected intervals between the cathode and the anode to excite the apparatus.

34. An electric system having, in combination, a gaseous-conductor device having at least three electrodes of the type in which an electric discharge between two main electrodes may be initiated by changing the potential of the third electrode, a condenser shunted across the main electrodes, a charging circuit for charging said condenser comprising a source of direct current, an inductance and an electric check valve connected in series, means for causing the charging current to flow always in the same direction in the charging circuit, and means for varying the potential of said third electrode to cause said condenser to discharge through said device.

35. Apparatus for producing electrical-energy flashes comprising a flashing lamp, a condenser, a source of potential for charging the condenser, means connected in series circuit with the energy source and with the condenser for charging the condenser comprising an electric check valve and an inductance, and means for discharging the condenser into the flashing lamp comprising a gaseous-discharge device having at least three electrodes and of the type in which the maximum potential which can be established between two main electrodes without appreciable current flow therebetween may be controlled by controlling the potential between one of said main electrodes and a third electrode, said condenser-discharge means also including means for impressing a voltage impulse between the third electrode and one of the main electrodes of said gaseous-discharge device.

36. Apparatus for producing electrical-energy flashes comprising a flashing lamp, a condenser, a source of direct-current potential for charging the condenser, means connected in series circuit with the energy source and with the condenser for charging the condenser comprising an electric check valve and an inductance, and means for discharging the condenser into the flashing lamp, the condenser-discharge means comprising a gaseous-discharge device having at least three electrodes and of the type in which the maximum potential which can be established between two main electrodes without appreciable current flow therebetween may be controlled by controlling the potential between one of said main electrodes and a third electrode, and means for impressing a voltage impulse between the third electrode and one of the main electrodes of said gaseous-discharge device.

37. In combination with apparatus adapted for excitation by electrical impulses, means for exciting such apparatus comprising a condenser, a source of energy for charging the condenser, means connected in series circuit with the energy source and with the condenser for charging the condenser comprising an electric check valve and an inductance, means for discharging the condenser at selected intervals, and means for conveying to the apparatus the voltage impulse which occurs at the instant that current ceases to flow through said electric check valve.

38. An electric system having, in combination, a condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce a pulse of electric energy, the gaseous-conductor means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current and a discharge device for charging the condenser, a discharging circuit for the condenser connected to the gaseous-conductor means, the electrical parameters of the con-

denser-discharging circuit being such that, if the gaseous-conductor means were substantially equally conductive both in the said one direction and the said opposite direction, the condenser-discharging circuit would be oscillatory, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor means to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce a pulse of electric energy.

39. An electric system having, in combination, a condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce a pulse of electric energy, the gaseous-conductor means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, an electron-discharge device having a control electrode, a circuit having a source of direct current and including the electron-discharge device for charging the condenser, means under the control of the control electrode for connecting the condenser to the condenser-charging circuit to charge the condenser from the source and for disconnecting the condenser from the condenser-charging circuit after the condenser has become charged, a discharging circuit for the condenser connected to the gaseous-conductor means, the electrical parameters of the condenser-discharging circuit being such that, if the gaseous-conductor means were substantially equally conductive both in said one direction and the said opposite direction, the condenser-discharging circuit would be oscillatory, means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor means at a time when the condenser is disconnected from the condenser-charging circuit to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce a pulse of electric energy, and means for controlling the control electrode to maintain the condenser disconnected from the condenser-charging circuit a predetermined time after the discharge of the condenser.

40. An electric system having, in combination, a condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce a pulse of electric energy, the gaseous-conductor means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current for charging the condenser, means for connecting the condenser to the condenser-charging circuit to charge the condenser from the source and for disconnecting the condenser from the condenser-charging circuit after the condenser has become charged, a discharging circuit for the condenser connected to the gaseous-conductor means, the electrical parameters of the condenser-discharging circuit being such that, if the gaseous-conductor means were substantially equally conductive both in the said one direction and the said opposite direction, the condenser-discharging circuit would be oscillatory, means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor means at a time when the condenser is disconnected from the condenser-charging circuit to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce a pulse of electric energy, and means for maintaining the condenser disconnected from the condenser-charging circuit a predetermined time after the discharge of the condenser.

41. An electric system having in combination, a condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce a pulse of electric energy, a circuit having a source of direct current for charging the condenser, means for connecting the condenser to the condenser-charging circuit to charge the condenser from the source and for disconnecting the condenser from the condenser-charging circuit after the condenser has become charged, a discharging circuit for the condenser connected to the gaseous-conductor means, means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor means at a time when the condenser is disconnected from the condenser-charging circuit to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce a pulse of electric energy, and means for maintaining the condenser disconnected from the condenser-charging circuit a predetermined time after the discharge of the condenser.

42. An electric system having, in combination, a condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce a pulse of electric energy, the gaseous-conductor means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current and a discharge device for charging the condenser, a discharging circuit for the condenser connected to the gaseous-conductor means, the electrical parameters of the condenser-discharging circuit being such that, if the gaseous-conductor means were substantially equally conductive both in the said one direction and the said opposite direction, the condenser-discharging circuit would be oscillatory, and means comprising a discharge device for applying a condenser-discharge-initiating stimulus to the gaseous-conductor means to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce a pulse of electric energy.

43. In apparatus for producing pulses of electric energy, a condenser, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, an inductance, a circuit having a source of direct-current potential and including the means having rectifier characteristics and the inductance for charging the condenser to a predetermined potential higher than the potential of the source, a discharging circuit for the condenser, and means

for suddenly discharging the condenser through the condenser-discharging circuit to produce a pulse of electric energy.

44. An electric system having, in combination, normally non-conductive gaseous-conductor means having at least three electrodes of the type in which an electric discharge between two main electrodes may be initiated by changing the potential of the third electrode, a condenser connected to the gaseous-conductor means to discharge through the gaseous-conductor means between the main electrodes when the gaseous-conductor means is conductive to produce a pulse of electric energy, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, an inductance, a circuit having a source of direct current and including the means having rectifier characteristics and the inductance connected to the gaseous-conductor means in series for charging the condenser, a discharging circuit for the condenser connected to the gaseous-conductor means, and means for changing the potential of the third electrode to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means between the main electrodes to produce a pulse of electric energy.

45. An electric system having, in combination, a condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce a pulse of electric energy, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of current and including the means having rectifier characteristics for charging the condenser, the electrical parameters of the condenser-charging circuit being such that, if the means having rectifier characteristics were substantially equally conductive in both the said one direction and the said opposition direction, the condenser-charging circuit would be oscillatory, a discharging circuit for the condenser connected to the gaseous-conductor means, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor means to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce a pulse of electric energy.

46. In apparatus for producing pulses of electric energy, a condenser, a circuit having a source of direct current for charging the condenser, the electrical parameter of the condenser-charging circuit being such that the condenser-charging circuit is oscillatory, a discharging circuit for the condenser, and means for suddenly discharging the condenser through the condenser-discharging circuit to produce a pulse of electric energy.

47. An electric system having, in combination, normally non-conductive gaseous-conductor means having at least three electrodes of the type in which an electric discharge between two main electrodes may be initiated by changing the potential of the third electrode, a condenser connected to the gaseous-conductor means to discharge through the gaseous-conductor means between the main electrodes when the gaseous-conductor means is conductive to produce a pulse of electric energy, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current and including the means having rectifier characteristics for charging the condenser, the electrical parameters of the condenser-charging circuit being such that, if the means having rectifier characteristics were substantially equally conductive in both the said one direction and the said opposite direction, the condenser-charging circuit would be oscillatory, a discharging circuit for the condenser connected to the gaseous-conductor means, and means for changing the potential of the third electrode to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means between the main electrodes to produce a pulse of electric energy.

48. In apparatus for producing pulses of electric energy, a condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce a pulse of electric energy, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, an inductance, a circuit having a source of direct-current potential and including the means having rectifier characteristics and the inductance connected to the gaseous-conductor means for charging the condenser to a predetermined potential higher than the potential of the source, a discharging circuit for the condenser connected to the gaseous-conductor means, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor means to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce a pulse of electric energy.

49. In apparatus for producing pulses of electric energy, a condenser, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions an inductance, a circuit having a source of direct-current potential and including the means having rectifier characteristics and the inductance for charging the condenser to a predetermined potential higher than the potential of the source, the electrical parameters of the condenser-charging circuit being such that, if the means having rectifier characteristics were substantially equally conductive in both the said one direction and the said opposite direction, the condenser-charging circuit would be oscillatory, a discharging circuit for the condenser, a discharge device having at least three electrodes of a type in which the maximum potential that can be established between two principal electrodes without appreciable current flow therebetween may be controlled by controlling the potential of the third electrode, and means for changing the potential of the third electrode to effect a sudden discharge of the condenser through the condenser-discharging circuit to produce a pulse of electric energy.

50. In apparatus for producing pulses of electric energy, a condenser, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of energy and including the means having rectifier characteristics connected in series for charging the condenser, the electrical parameters of the condenser–charging circuit being such that, if the means having rectifier characteristics were substantially equally conductive in both the said one direction and the said opposite direction, the condenser-charging circuit would be oscillatory, a discharging circuit for the condenser, and means for suddenly discharging the condenser through the condenser-discharging circuit to produce a pulse of electric energy.

51. An electric system having, in combination, normally non-conductive gaseous-conductor means having at least three electrodes of the type in which an electric discharge between two main electrodes may be initiated by changing the potential of the third electrode, a condenser connected to the gaseous-conductor means to discharge through the gaseous-conductor means between the main electrodes when the gaseous-conductor means is conductive to produce a pulse of electric energy, a circuit having a source of direct current, inductance and resistance for charging the condenser, the electrical parameters of the condenser-charging circuit being such that the condenser-charging circuit is oscillatory, a discharging circuit for the condenser connected to the gaseous-conductor means, and means for changing the potential of the third electrode to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means between the main electrode to produce a pulse of electric energy.

52. A light-flash producer having, in combination, a condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce a light flash of substantial illumination intensity, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of current and including the means having rectifier characteristics for charging the condenser, the electrical parameters of the condenser-charging circuit being such that, if the means having rectifier characteristics were substantially equally conductive in both the said one direction and the said opposite direction, the condenser-charging circuit would be oscillatory, a discharging circuit for the condenser connected to the gaseous-conductor means, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor means to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce a light flash of substantial illumination intensity.

53. A light-flash producer having, in combination, normally non-conductive gaseous-conductor means, having at least three electrodes of the type in which an electric discharge between two main electrodes may be initiated by changing

the potential of the third electrode, a condenser connected to the gaseous-conductor means to discharge through the gaseous-conductor means between the main electrodes when the gaseous-conductor means is conductive to produce a light flash of substantial illumination intensity, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, an inductance, a circuit having a source of direct current and including the means having rectifier characteristics and the inductance connected to the gaseous-conductor means in series for charging the condenser, a discharging circuit for the condenser connected to the gaseous-conductor means, and means for changing the potential of the third electrode to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means between the main electrodes to produce a light flash of substantial illumination intensity.

54. A light-flash producer having, in combination, normally non-conductive gaseous-conductor means having at least three electrodes of the type in which an electric discharge between two main electrodes may be initiated by changing the potential of the third electrode, a condenser connected to the gaseous-conductor means to discharge through the gaseous-conductor means between the main electrodes when the gaseous-conductor means is conductive to produce a light flash of substantial illumination intensity, a circuit having a source of direct current connected to the gaseous-conductor means for charging the condenser, the electrical parameters of the condenser-charging circuit being such that the condenser-charging circuit is oscillatory, a discharging circuit for the condenser connected to the gaseous-conductor means, and means for changing the potential of the third electrode to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means between the main electrodes to produce a light flash of substantial illumination intensity.

55. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce a pulse of electric energy therein, the load having two electrodes, a normally non-conductive gaseous-conductor device having two principal electrodes and a control electrode, a conductor connecting one of the principal electrodes to one of the load electrodes, conductors connecting the other principal electrode and the other load electrode to the condenser, a circuit having a source of direct current and a discharge device for charging the condenser to a voltage of magnitude insufficient to effect a discharge of the condenser through the gaseous-conductor device between the principal electrodes and through the load between the load electrodes when the gaseous-conductor device is non-conductive but sufficient to effect a discharge of the condenser through the gaseous-conductor device between the principal electrodes and through the load between the load electrodes to produce a pulse of electric energy in the load when the gaseous-conductor device is conductive, and a trip circuit comprising a second discharge device, means for connecting the second discharge device to the control electrode, means for impressing an

impulse upon the second discharge device, means controlled by the second discharge device in response to the impulse for producing a sudden violent electrical transient impulse, and means for transmitting the transient impulse to the control electrode to render the gaseous-conductor device suddenly conductive in order to effect a discharge of the condenser through the gaseous-conductor device between the principal electrodes and through the load between the load electrodes to produce a pulse of electric energy in the load.

56. A light-flash producer having, in combination, a condenser, a gaseous-conductor lamp through which the condenser may discharge to produce a light flash of substantial illumination intensity, the lamp having two electrodes, a normally non-conductive gaseous-conductor device having two principal electrodes and a control electrode, a conductor connecting one of the principal electrodes to one of the lamp electrodes, conductors connecting the other principal electrode and the other lamp electrode to the condenser, a circuit having a source of direct current and a discharge device for charging the condenser to a voltage of magnitude insufficient to effect a discharge of the condenser through the gaseous-conductor device between the principal electrodes and through the lamp between the lamp electrodes when the gaseous-conductor device is non-conductive but sufficient to effect a discharge of the condenser through the gaseous-conductor device between the principal electrodes and through the lamp between the lamp electrodes to produce a light flash when the gaseous-conductor device is conductive, and a trip circuit comprising a second discharge device, means for connecting the second discharge device to the control electrode, means for impressing an impulse upon the second discharge device, means controlled by the second discharge device in response to the impulse for producing a sudden violent electrical transient impulse, and means for transmitting the transient impulse to the control electrode to render the gaseous-conductor device suddenly conductive in order to effect a discharge of the condenser through the gaseous-conductor device between the principal electrodes and through the lamp between the lamp electrodes to produce a light flash of substantial illumination intensity.

57. A light-flash producer having, in combination, a condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce a light flash of substantial illumination intensity, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, an inductance, a circuit having a source of direct-current potential and including the means having rectifier characteristics and the inductance connected to the gaseous-conductor means for charging the condenser to a potential higher than the potential of the source, a discharging circuit for the condenser connected to the gaseous-conductor means, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor means to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce a light flash of substantial illumination intensity.

58. In apparatus for producing light flashes of substantial illumination intensity, a condenser, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current and including the means having rectifier characteristics for charging the condenser, the electrical parameters of the condenser-charging circuit being such that, if the means having rectifier characteristics were substantially equally conductive in both the said one direction and the said opposite direction, the condenser-charging circuit would be oscillatory, a discharging circuit for the condenser, and means for suddenly discharging the condenser through the condenser-discharging circuit to produce a light flash of substantial illumination intensity.

59. A light-flash producer having, in combination, normally non-conductive gaseous-conductor means having at least three electrodes of the type in which an electric discharge between two main electrodes may be initiated by changing the potential of the third electrode, a condenser connected to the gaseous-conductor means to discharge through the gaseous-conductor means between the main electrodes when the gaseous-conductor means is conductive to produce a light flash of substantial illumination intensity, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of current and including the means having rectifier characteristics for charging the condenser, the electrical parameters of the condenser-charging circuit being such that, if the means having rectifier characteristics were substantially equally conductive in both the said one direction and the said opposite direction, the condenser-charging circuit would be oscillatory, a discharging circuit for the condenser connected to the gaseous-conductor means, and means for changing the potential of the third electrode to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means between the main electrodes to produce a light flash of substantial illumination intensity.

60. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce a pulse of electric energy therein, a normally non-conductive gaseous-conductor device, a circuit having a source of direct current and a discharge device for charging the condenser, means whereby the condenser is charged by the condenser-charging circuit from the source without producing a substantial pulse in the load during the charging of the condenser, a discharging circuit for the condenser connected to the gaseous-conductor device and the load, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device and the load to produce a pulse of electric energy in the load.

61. A light-flash producer having, in combination, a condenser, a gaseous-conductor lamp through which the condenser may discharge to produce a light flash of substantial illumination

intensity, a normally non-conductive gaseous-conductor device, a circuit having a source of direct current and a discharge device for charging the condenser, a discharging circuit for the condenser connected to the gaseous-conductor device and the lamp, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device and the lamp to produce a light flash of substantial illumination intensity.

62. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce a pulse of electric energy, a normally non-conductive gaseous-conductor device, the gaseous-conductor device having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current and a discharge device for charging the condenser, a discharging circuit for the condenser connected to the gaseous-conductor device and the load, the electrical parameters of the condenser-discharging circuit being such that, if the gaseous-conductor device were substantially equally conductive both in the said one direction and the said opposite direction, the condenser-discharging circuit would be oscillatory, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device and the load to produce a pulse of electric energy in the load.

63. A light-flash producer having, in combination, a condenser, a gaseous-conductor lamp for producing light flashes of substantial illumination intensity, a normally non-conductive gaseous-conductor device, the gaseous-conductor device having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current and a discharge device for charging the condenser, a discharging circuit for the condenser connected to the gaseous-conductor device and the lamp, the electrical parameters of the condenser-discharging circuit being such that, if the gaseous-conductor device were substantially equally conductive both in the said one direction and the said opposite direction, the condenser-discharging circuit would be oscillatory, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device and the lamp to produce a light flash of substantial illumination intensity.

64. An electric system having, in combination, a condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce a pulse of electric energy, a circuit having a source of direct current for charging the condenser, means for rendering the condenser-charging circuit effective to charge the condenser from the source, a discharging circuit for the condenser connected to the gaseous-conductor means, means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor means to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce a pulse of electric energy, and means for rendering the condenser-charging circuit ineffective to charge the condenser a predetermined time after the discharge of the condenser.

65. An electric system having, in combination, a condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce a pulse of electric energy, an electron-discharge device having a control electrode, a circuit having a source of energy and including the electron-discharge device for charging the condenser, means under the control of the control electrode for connecting the condenser to the condenser-charging circuit to charge the condenser from the source and for disconnecting the condenser from the condenser-charging circuit after the condenser has become charged, a discharging circuit for the condenser connected to the gaseous-conductor means, means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor means at a time when the condenser is disconnected from the condenser-charging circuit to render the gaseous-conductor means suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce a pulse of electric energy, and means for controlling the control electrode to maintain the condenser disconnected from the condenser-charging circuit a predetermined time after the discharge of the condenser.

66. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce a pulse of electric energy therein, the load having two electrodes, a normally non-conductive gaseous-conductor tube having two principal electrodes and a control electrode, a conductor connecting one of the principal electrodes to one of the load electrodes, conductors connecting the other principal electrode and the other load electrode to the condenser, a circuit having a source of direct current and a rectifier for charging the condenser, a discharging circuit for the condenser connected to the gaseous-conductor tube and the load, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor tube to render the gaseous-conductor tube suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and through the gaseous-conductor tube between the principal electrodes and through the load between the load electrodes to produce a pulse of electric energy in the load.

67. A light-flash producer having, in combination, a condenser, a lamp through which the condenser may discharge to produce a light flash of substantial illumination intensity, the lamp having two electrodes, a normally non-conductive gaseous-conductor tube having two principal electrodes and a control electrode, a conductor connecting one of the principal electrodes to one of the lamp electrodes, conductors connecting the other principal electrode and the other lamp electrode to the condenser, a circuit having a source of direct current and a rectifier for charging the

condenser, a discharging circuit for the condenser connected to the gaseous-conductor tube and the lamp, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor tube to render the gaseous-conductor tube suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and through the gaseous-conductor tube between the principal electrodes and through the lamp between the lamp electrodes to produce a flash of light of substantial illumination intensity.

68. An electric system having, in combination, a condenser, means for charging the condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce pulses of electric energy, a discharging circuit for the condenser connected to the gaseous-conductor means, means for periodically applying a condenser-discharge-initiating stimulus to the gaseous-conductor means to render the gaseous-conductor means suddenly conductive periodically in order to effect periodic sudden discharges of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce pulses of electric energy, and means whereby the means for periodically applying the condenser-discharge-initiating stimulus operates during times short compared to the intervals between successive discharges of the condenser.

69. An electric system having, in combination, a condenser, means for discharging the condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce pulses of electric energy having two principal electrodes and a control electrode, a discharging circuit for the condenser connected to the gaseous-conductor means, means for periodically modifying the potential of the control electrode to render the gaseous-conductor means suddenly conductive periodically in order to effect periodic sudden discharges of the condenser through the condenser-discharging circuit and the gaseous-conductor means between the principal electrodes to produce pulses of electric energy, and means whereby the modifying means operates to modify the potential of the control electrode during times short compared to the intervals between successive discharges of the condenser.

70. A light-flash producer having, in combination, a condenser, means for charging the condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce light flashes of substantial illumination intensity, a discharging circuit for the condenser connected to the gaseous-conductor means, means for periodically applying a condenser-discharge-initiating stimulus to the gaseous-conductor means to render the gaseous-conductor means suddenly conductive periodically in order to effect periodic sudden discharges of the condenser through the condenser-discharging circuit and the gaseous-conductor means to produce light flashes of substantial illumination intensity, and means whereby the means for periodically applying the condenser-discharge-initiating stimulus operates during times short compared to the intervals between successive discharges of the condenser.

71. A light-flash producer having, in combination, a condenser, means for charging the condenser, normally non-conductive gaseous-conductor means through which, when conductive, the condenser may discharge to produce light flashes of substantial illumination intensity having two principal electrodes and a control electrode, a discharging circuit for the condenser connected to the gaseous-conductor means, means for periodically modifying the potential of the control electrode to render the gaseous-conductor means suddenly conductive periodically in order to effect periodic sudden discharges of the condenser through the condenser-discharging circuit and the gaseous-conductor means between the principal electrodes to produce light flashes of substantial illumination intensity, and means whereby the modifying means operates to modify the potential of the control electrode during times short compared to the intervals between successive discharges of the condenser.

72. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce a pulse of electric energy therein, a normally non-conductive gaseous-conductor device having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current for charging the condenser, a discharging circuit for the condenser connected to the gaseous-conductor device and the load, the electrical parameters of the condenser-discharging circuit being such that, if the gaseous-conductor device were substantially equally conductive both in the said one direction and the said opposite direction, the condenser-discharging circuit would be oscillatory, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device and the load to produce a pulse of electric energy in the load.

73. A light-flash producer having, in combination, a condenser, a lamp through which the condenser may discharge to produce a light flash of substantial illumination intensity, a normally non-conductive gaseous-conductor device having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current for charging the condenser, a discharging circuit for the condenser connected to the gaseous-conductor device and the lamp, the electrical parameters of the condenser-discharging circuit being such that, if the gaseous-conductor device were substantially equally conductive both in the said one direction and the said opposite direction, the condenser-discharging circuit would be oscillatory, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device and the lamp to produce a light flash of substantial illumination intensity.

74. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce a pulse of electric energy therein, a normally non-conductive gaseous-conductor device, a circuit having a source of direct current for charging the condenser, the electrical parameters of the con-

denser-charging circuit being such that the condenser-charging circuit is oscillatory, a discharging circuit for the condenser connected to the gaseous-conductor device and the load, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device and the load to produce a pulse of electric energy.

75. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce a pulse of electric energy therein, a normally non-conductive gaseous-conductor device having two principal electrodes and a control electrode, means having rectifier characteristics enabling it to conduct appreciable current in one direction between the principal electrodes but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current and including the means having rectifier characteristics for charging the condenser, the electrical parameters of the condenser-charging circuit being such that, if the means having rectifier characteristics were substantially equally conductive both in the said one direction and the said opposite direction, the condenser-charging circuit would be oscillatory, a discharging circuit for the condenser connected to the gaseous-conductor device and the load, and means for applying a condenser-discharge-initiating stimulus to the control electrode to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device between the principal electrodes and the load to produce a pulse of electric energy in the load.

76. A light-flash producer having, in combination, a condenser, a lamp through which the condenser may discharge to produce a light flash of substantial illumination intensity, a normally non-conductive gaseous-conductor device, a circuit having a source of direct current for charging the condenser, the electrical parameters of the condenser-charging circuit being such that the condenser-charging circuit is oscillatory, a discharging circuit for the condenser connected to the gaseous-conductor device and the lamp, and means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device and the lamp to produce a light flash of substantial illumination intensity.

77. A light-flash producer having, in combination, a condenser, a lamp through which the condenser may discharge to produce a light flash of substantial illumination intensity, a normally non-conductive gaseous-conductor device having two principal electrodes and a control electrode, means having rectifier characteristics enabling it to conduct appreciable current in one direction between the principal electrodes but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current and including the means having rectifier characteristics for charging the condenser, the electrical parameters of the condenser-charging circuit being such that, if the means having rectifier characteristics were substantially equally conductive both in the said one direction and the said opposite direction, the condenser-charging circuit would be oscillatory, a discharging circuit for the condenser connected to the gaseous-conductor device and the lamp, and means for applying a condenser-discharge-initiating stimulus to the control electrode to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device between the principal electrodes and the lamp to produce a light flash of substantial illumination intensity.

78. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce a pulse of electric energy therein, a normally non-conductive gaseous-conductor device, a circuit having a source of energy for charging the condenser, means for connecting the condenser to the condenser-charging circuit to charge the condenser from the source and for disconnecting the condenser from the condenser-charging circuit after the condenser has become charged, a discharging circuit for the condenser connected to the gaseous-conductor device and the load, means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device at a time when the condenser is disconnected from the condenser-charging circuit to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device and the load to produce a pulse of electric energy in the load, and means for maintaining the condenser disconnected from the condenser-charging circuit a predetermined time after the discharge of the condenser.

79. A light-flash producer having, in combination, a condenser, a lamp through which the condenser may discharge to produce a light flash of substantial illumination intensity, a normally non-conductive gaseous-conductor device having two principal electrodes and a control electrode, a circuit having a source of energy for charging the condenser, means for connecting the condenser to the condenser-charging circuit to charge the condenser from the source and for disconnecting the condenser from the condenser-charging circuit after the condenser has become charged, a discharging circuit for the condenser connected to the gaseous-conductor device and the lamp, means for applying a condenser-discharge-initiating stimulus to the gaseous-conductor device at a time when the condenser is disconnected from the condenser-charging circuit to render the gaseous-conductor device suddenly conductive in order to effect a sudden discharge of the condenser through the condenser-discharging circuit and the gaseous-conductor device between the principal electrodes and the lamp to produce a light flash of substantial illumination intensity, and means for maintaining the condenser disconnected from the condenser-charging circuit a predetermined time after the discharge of the condenser.

80. An electric system having, in combination, a condenser, means for charging the condenser, a load through which the condenser may discharge to produce pulses of electric energy therein, a normally non-conductive gaseous-conductor device having two principal electrodes and a control electrode, a discharging circuit for the condenser connected to the gaseous-conductor de-

vice and the load, means for periodically modifying the potential of the control electrode to render the gaseous-conductor device suddenly conductive periodically in order to effect periodic sudden discharges of the condenser through the condenser-discharging circuit and the gaseous-conductor device between the principal electrodes and the load to produce pulses of electric energy in the load, and means whereby the modifying means operates to modify the potential of the control electrode during times short compared to the intervals between successive discharges of the condenser.

81. A light-flash producer having, in combination, a condenser, means for charging the condenser, a lamp through which the condenser may discharge to produce light flashes of substantial illumination intensity, a normally non-conductive gaseous-conductor device, a discharging circuit for the condenser connected to the gaseous-conductor device and the lamp, means for periodically applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive periodically in order to effect periodic sudden discharges of the condenser through the condenser-discharging circuit and the gaseous-conductor device and the lamp to produce light flashes of substantial illumination intensity, and means whereby the means for periodically applying the condenser-discharge-initiating stimulus operates during times short compared to the intervals between successive discharges of the condenser.

82. An electric system having, in combination, a condenser, a load through which the condenser may discharge to produce pulses of electric energy therein, a normally non-conductive gaseous-conductor device having two principal electrodes and a control electrode having rectifier characteristics enabling it to conduct appreciable current in one direction between the principal electrodes but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a discharging circuit for the condenser connected to the gaseous-conductor device and the load, the electrical parameters of the condenser-discharging circuit being such that, if the gaseous-conductor device were substantially equally conductive both in the said one direction and the said opposite direction, the condenser-discharging circuit would be oscillatory, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current and including the means having rectifier characteristics for charging the condenser, the electrical parameters of the condenser-charging circuit being such that, if the means having rectifier characteristics were substantially equally conductive both in the said one direction and the said opposite direction of the means having rectifier characteristics, the condenser-charging circuit would be oscillatory, means for periodically modifying the potential of the control electrode to render the gaseous-conductor device suddenly conductive periodically in order to effect periodic sudden discharges of the condenser through the condenser-discharging circuit and the gaseous-conductor device between the principal electrodes and the load to produce pulses of electric energy in the load, and means whereby the modifying means operates to modify the potential of the control electrode during times short compared to the intervals between successive discharges of the condenser.

83. A light-flash producer having, in combination, a condenser, a lamp through which the condenser may discharge to produce light flashes of substantial illumination intensity, a normally non-conductive gaseous-conductor device having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a discharging circuit for the condenser connected to the gaseous-conductor device and the lamp, the electrical parameters of the condenser-discharging circuit being such that, if the gaseous-conductor device were substantially equally conductive both in the said one direction and the said opposite direction, the condenser-discharging circuit would be oscillatory, means having rectifier characteristics enabling it to conduct appreciable current in one direction but preventing it from conducting appreciable current in the opposite direction under predetermined conditions, a circuit having a source of direct current and including the means having rectifier characteristics for charging the condenser, the electrical parameters of the condenser-charging circuit being such that, if the means having rectifier characteristics were substantially equally conductive both in the said one direction and the said opposite direction of the means having rectifier characteristics, the condenser-charging circuit would be oscillatory, means for periodically applying a condenser-discharge-initiating stimulus to the gaseous-conductor device to render the gaseous-conductor device suddenly conductive periodically in order to effect periodic sudden discharges of the condenser through the condenser-discharging circuit and the gaseous-conductor device and the lamp to produce light flashes of substantial illumination intensity, and means whereby the means for periodically applying the condenser-discharge-initiating stimulus operates during times short compared to the intervals between successive discharges of the condenser.

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Certificate of Correction

Patent No. 2,478,907 **August 16, 1949**

HAROLD E. EDGERTON

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

Column 12, line 23, for the word "condenser" read *condensers*; column 19, line 70, for "indutance" read *inductance*; column 23, line 47, for "opposition" read *opposite*; line 61, for "parameter" read *parameters*; column 24, line 54, after "conditions" insert a comma; column 25, line 73, after "means" strike out the comma; column 31, line 33, for "discharging" read *charging*;

and that the said Letters Patent should be read with these corrections 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.