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METHOD OF AND APPARATUS FOR THE CONTROL OF ELECTRIC IMPULSES

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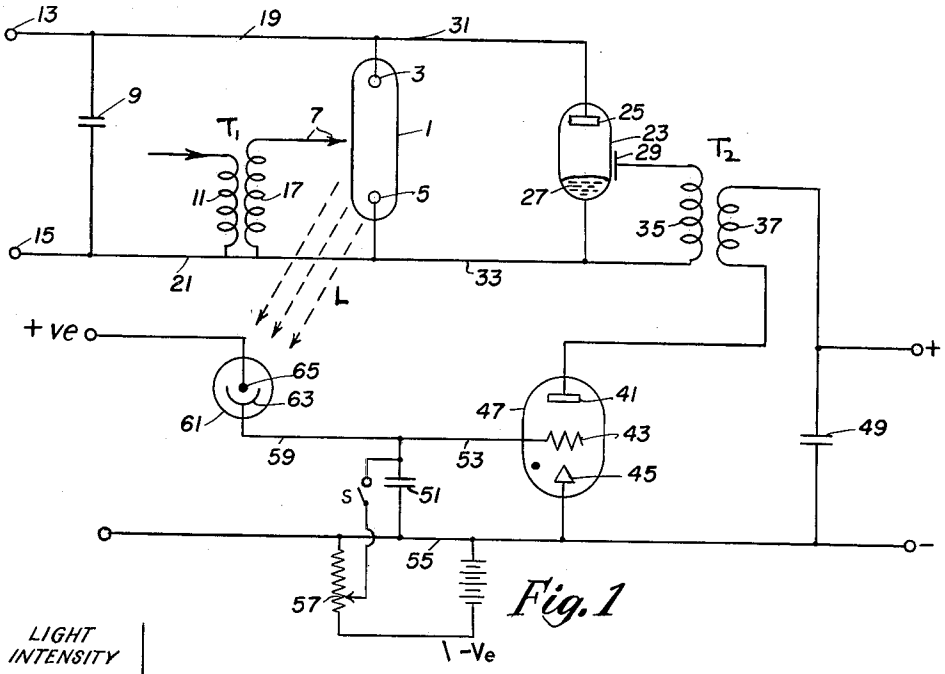


Fig. 1

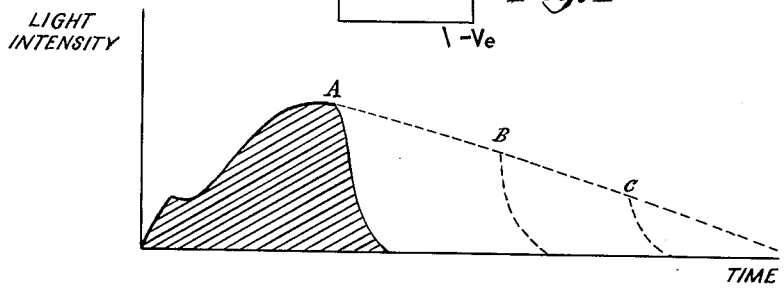


Fig. 2

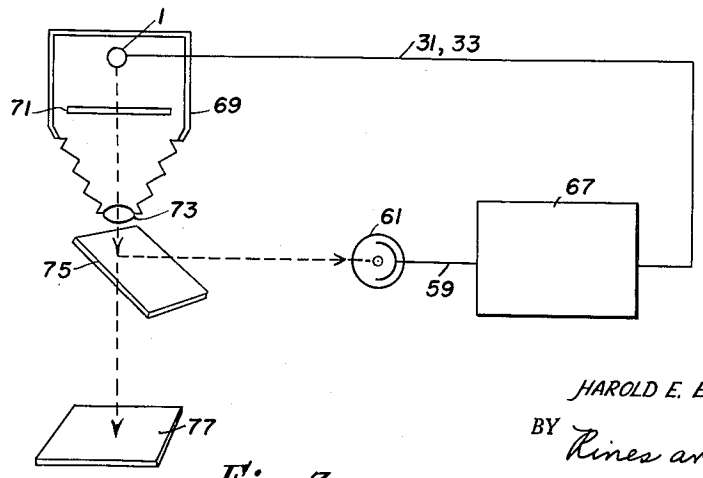


Fig. 3

INVENTOR.
HAROLD E. EDGERTON
BY Rines and Rines
ATTORNEYS

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METHOD OF AND APPARATUS FOR THE CONTROL OF ELECTRIC IMPULSES

Harold E. Edgerton, Belmont, Mass., assignor to Edgerton, Germeshausen & Grier, Inc., Boston, Mass., a corporation of Massachusetts

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The present invention relates to methods of and apparatus for controlling electric impulses, and, more particularly, to controlling the duration of light flashes which may be used for photographic or other purposes.

Various types of exposure or light meters have been developed for determining the quantity of light energy produced by a flash device, such as, for example, a gaseous-discharge flash tube or lamp, in order to effect proper exposure of a photographic film and the like to objects or scenes to be reproduced. A successful light-integrating exposure meter of this character is described, for example, in my prior United States Letters Patent No. 2,588,368, issued March 11, 1952. In order to provide for predetermined exposures, however, it has also been proposed to calibrate the flash-producing electrical circuits in order that flashes of different intensity may be produced, depending upon the desired exposure. Where, for example, negatives are to be enlarged or printed upon a photographic film, it has been proposed to control the intensity of the flashes of a flash lamp in accordance with the density of the negative. The adjustment of the flash-lamp circuit in order to pre-determine the light energy of the flash is effected after a measurement or analysis of the density variation of the negative. This procedure is not only time-consuming, but it is really not suited to high-speed commercial printing processes.

An object of the present invention, accordingly, is to provide a new and improved method of and apparatus for automatically controlling the light energy emitted by a flash device during a flash impulse.

A further object is to provide an improved method and apparatus of this character that are particularly suited for enlarging or printing processes, and that operate automatically to control the energy of the emitted flash of light in accordance with the density of a negative or other medium placed in the path of the light.

An additional object resides in providing an improved method of and apparatus for controlling the duration of any type of electric impulse in accordance with the energy produced during the impulse, in order automatically to terminate the impulse when a desired predetermined amount of energy has been produced. In summary, therefore, the invention resides, from perhaps its broadest point of view, in monitoring the energy of an impulse that would normally extend over a predetermined short interval of time to produce a predetermined quantity of energy. At the instant at which the total amount of monitored energy has reached a predetermined value less than the before-mentioned predetermined quantity, however, the production of the impulse is automatically terminated. Preferred circuit and other details are hereinafter set forth.

Other and further objects will be described hereinafter and will be more fully pointed out in the appended claims.

The invention will now be explained in connection with the accompanying drawing,

FIG. 1 of which is a schematic circuit diagram of an apparatus constructed in accordance with a preferred embodiment of the present invention;

FIG. 2 is a graph explanatory of the operation of the invention; and

FIG. 3 is a combined schematic and block diagram

illustrating a system in which the present invention may be utilized.

While the invention will hereinafter be described in connection with its application to the monitoring of the light energy given off by a flash device, it is to be understood that the invention, as before stated, is of broader utility and may obviously be applied wherever it is desired to control the amount of electric energy produced in an electric-energy impulse through monitoring the actual energy produced during the impulse and then automatically adjusting the duration of the impulse.

Referring to FIG. 1, a flash device 1 is shown for illustrative purposes as provided with a pair of principal electrodes 3 and 5 disposed within a gas-filled lamp, tube or envelope 1, and a trigger electrode 7, which may be either within or outside the tube 1, as illustrated. This flash device 1 may, however, be of any desired type, including discharge gaps, several such being described, for example, in my prior United States Letters Patent No. 2,426,602, issued September 2, 1947 and 2,478,901 and 2,478,906, issued August 16, 1949, and in United States Letters Patent No. 2,722,629, issued on November 1, 1955 to Kenneth J. Germeshausen. In the illustrated system, one or more flash or storage condensers or capacitors 9 is or are charged with relatively high voltage from a source of potential, not shown, connected to the terminals 13 and 15. The condenser or capacitor 9 is connected by an upper conductor 19 and a lower conductor 21 to the respective principal electrodes 3 and 5 of the flash device 1. The voltage of the charged capacitor 9, however, is not sufficient of itself to effect an electrical gaseous-discharge through the flash tube 1, between the anode and cathode principal electrodes 3 and 5, except upon energization of the trigger electrode 7. A trigger transformer T_1, comprising a primary winding 11 to which a trigger impulse may be applied at any desired instant of time, and a preferably step-up secondary winding 17, impresses a trigger impulse between the trigger electrode 7 and the principal electrode 5. The electric energy stored in the capacitor 9 becomes thereupon delivered to the flash-tube load 1 by the conductors 19 and 21, producing a discharge between the principal electrodes 3 and 5 of the flash tube 1. A flash of light energy is thus produced in the tube 1 and is emitted through the walls of the envelope thereof, as indicated by the parallel dash lines L.

In accordance with the present invention, the light energy thus produced by the flash device 1, as the voltage stored in the capacitor 9 is delivered to the load 1, is monitored by any suitable monitoring device. That monitoring device is illustrated in the form of a preferred photoelectric cell 61, having an anode 65 connected to a positive voltage terminal +*ve*, and a cathode 63 connected by conductors 59 and 53 to the control electrode 43 of a first switching device or tube 47, as of the preferred gaseous-discharge or thyratron type. The cathode 45 of the switching device 47 is connected by conductor 55 to a negative potential terminal —. Any desired predetermined bias potential may be applied to the control electrode 43 through a variable potentiometer resistor or other impedance 57 from a further negative potential terminal —*ve*, upon closure of a switch S. The first switching gaseous-discharge device 47 may thus be normally biased so as to be nonconductive and hence ineffective as a switch. Connected between the anode or plate 41 and the cathode 45 of the switching tube 47, is a primary winding 37 of a further transformer T_2, connected in series circuit with a further storage capacitor 49, normally charged from the +, —, source of potential, indicated to the right thereof. The voltage stored in the capacitor 49 can not normally discharge between the anode 41 and the cathode 45 of the switching tube 47 in view of the before-mentioned negative bias applied to

the control electrode 43. When the photocell 61 has received sufficient light energy L from the flash tube 1 to charge positively to a sufficient degree an integrating capacitor 51, connected between the conductors 59 and 55, the bias upon the control electrode 43 of the tube 47 may be overcome. The tube 47 may then conduct, so that the capacitor 49 thereupon discharges its voltage through the effective switching tube 47 and through the primary winding 37 of the before-mentioned further transformer T_2.

A trigger impulse is thus induced in the secondary winding 35 of the transformer T_2 which may be applied to a trigger electrode 29 associated with a further switching device 23. The further switching device 23 is also illustrated as of the gaseous-discharge variety having an anode or plate 25, a cathode 27, as of the mercury-pool type, and the trigger electrode 29, shown as a band electrode disposed adjacent the pool cathode 27. The anode 25 of the switching tube 23 is connected by conductor 31 to the flash tube anode electrode 3 and the cathode 27 of the tube 23 is connected by conductor 33 to the flash tube cathode electrode 5. Upon the advent of the trigger impulse in the transformer T_2, produced by the rendering conductive of the normally ineffective first switching tube 47, in response to the monitoring of a predetermined value of light energy L from the flash tube 1, therefore, the further switching tube 23 may be rendered conductive, also. This establishes a by-pass for the energy being delivered from the capacitor 9 between the principal electrodes 3 and 5 of the flash tube 1, provided that the impedance of the switching tube 23, when conductive, is small compared with the impedance of the flash tube 1 while in the process of discharging. An effective short-circuit is thus provided by the conductive switching tube 23 across the principal electrodes 3 and 5 of the flash tube 1, terminating the delivery of energy from the capacitor 9 to the flash tube 1 and transferring that delivery, rather, to the lower-impedance shorting tube 23.

By appropriate setting of the bias resistor 57 and appropriate values of the integrating capacitor 51, therefore, the flash discharge produced through the flash tube 1 may be terminated through the operation of the first switching device 47 that controls the short-circuiting action of the second switching device 23, when the light energy produced by the flash tube 1 has reached any desired predetermined value.

Thus, in the photographic application of FIG. 3, the flash tube 1 is shown directing its light energy through a negative 71 of, for example, an enlarging camera 69 provided with a lens 73. The electrical circuits of FIG. 1 are schematically represented in FIG. 3 by the block 67. The light energy from the flash tube 1 is transmitted along the vertical dash line through a beam-splitting half-silvered mirror or other device 75 for applying part of the transmitted light energy to the monitor photocell 61 while the main light energy is transmitted to a film 77 for exposure. By pre-setting the value of the resistor 57 for any desired pre-determined value of integrated light energy, therefore, there will automatically be effected the correct exposure irrespective of the various densities of different negatives 71. This may be seen from the following considerations. Assume, for example, that the dotted envelope, illustrated in the graph of FIG. 2, represents, upon an expanded scale, the wave form of the light energy that would normally be produced by the flash tube 1 during a complete discharge of the flash capacitor 9 therethrough. The ordinate of this graph of FIG. 2 represents light intensity, and the abscissa represents time. This wave form is characteristic of light flashes produced in flash tubes, involving a rather steeply rising left-hand portion and a rather gradually sloping right-hand portion. If the flash were permitted to continue for its full duration, of course, the total flash might last the order of a few milliseconds; say, for example 4 milliseconds. With

a negative 71 that is quite dense, it may take substantially the full envelope of the light flash to provide the desired predetermined exposure; i.e. to provide a sufficient quantity of light energy, represented by the area bounded by the envelope of FIG. 2, to effect a desired exposure. If, however, a less dense negative 71 is used, more light energy will be transmitted through the negative 71 than in the preceding case, and, of course, the time duration of the flash impulse should be shorter if the desired uniform exposure is to be produced. It might be that the light flash should be terminated at the point C, which might, for example, be disposed at the three millisecond point along the abscissa. Under such circumstances, the total energy monitored by the photocell 61 and integrated by the flash conductor 51 will produce the short-circuiting action of the switching device 23 at the time C, thereby permitting only the predetermined amount of light energy, less than the quantity involved in the complete flash, to be produced. If, on the other hand, successively less dense negatives 71 are used, the light energy impulse may be automatically terminated more rapidly, as at the points B and A; say, at the two and one millisecond points along the abscissa, respectively. The invention may thus be most conveniently used in commercial enlarging and other photographic processes where high speed and no manual adjustments for varying-density negatives are desired.

As a typical illustration, the flash tube 1 may be of the high-pressure type disclosed in an article entitled "Xenon Flash Tube of Small Size," by Edgerton and Cathou, appearing in the October 1956 issue of the Review of Scientific Instruments. Such flashtubes have an impedance of the order of 1 to 5 ohms or so during the flashing process. The short-circuiting tube 23 may, on the other hand, be a mercury tube which will have an impedance of less than one-tenth of an ohm or so, when conducting.

Other types of low-resistance switches than the mercury tube 23 may, of course, be employed, such as, for example, a fast-acting relay having large contacts for carrying the large currents required in the application of the present invention. The switching tube 47 may, also, if desired, be replaced by mechanical or other switching devices, including transistors and magnetic devices, though the described circuit is considered to be preferred. Other types of trigger or switching circuits may also be used as discussed, for example, in the said Letters Patent. As before stated, moreover, the invention is not restricted to its use with a flash lamp 1 that is producing light energy; it may be more broadly employed to monitor the energy delivered by an impulse to any type of load, and to control the duration of the impulse in accordance with the monitoring of a predetermined value of energy less than the quantity of energy which would be produced if the impulse were permitted to continue for its full duration.

Further modifications will occur to those skilled in the art and all such are considered to fall within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A method of the character described that comprises delivering to a load an electric impulse that would normally extend over a predetermined short interval of time to produce a predetermined quantity of output energy in the load, monitoring the output energy in the load, determining the instant at which the total monitored energy has reached a predeterined value less than the said predetermined quantity, and thereupon bypassing from the load the delivery of the impulse thereto.

2. A method of the character described that comprises delivering to a load an electric impulse that would normally extend over a predetermined short interval of time to produce a predetermined quantity of radiant energy in the load, monitoring the radiant energy in the load, de-

termining the instant at which the total monitored energy has reached a predetermined value less than the said predetermined quantity, and thereupon bypassing from the load the delivery of the impulse thereto.

3. A method of the character described that comprises discharging through a flash device an electric impulse that would normally extend over a predetermined short interval of time to produce a predetermined quantity of light energy in the device, monitoring the light energy produced in the device, determining the instant at which the total monitored light energy has reached a predetermined value less than the said predetermined quantity, and thereupon by-passing from the device the discharging of the impulse therethrough.

4. A method of the character described that comprises discharging through a flash device an electric impulse that would normally extend over a predetermined short interval of time to produce a predetermined quantity of light energy in the device, integrating the light energy produced in the device, determining the instant at which the total integrated light energy has reached a predetermined value less than the said predetermined quantity, and thereupon by-passing from the device the discharging of the impulse therethrough.

5. A method of the character described that comprises discharging through a flash device an electric impulse that would normally extend over a predetermined short interval of time to produce a predetermined quantity of light energy, transmitting the light energy along a path of variable density, monitoring the light energy transmitted along the path, determining the instant at which the total monitored light energy has reached a predetermined value less than the said predetermined quantity, and thereupon by-passing from the device the discharging of the impulse therethrough, thereby to effect the transmission of the said predetermined value of light energy only irrespective of the density of the path.

6. A method of the character described that comprises discharging through a flash device an electric impulse that would normally extend over a predetermined short interval of time to produce a predetermined quantity of light energy in the device, transmitting the light energy to a film along a path in which a negative may be disposed in order to effect exposure of the negative to the film, monitoring the light energy transmitted through the negative, determining the instant at which the total monitored light energy has reached a predetermined value less than the said predetermined quantity, and thereupon by-passing from the device the discharging of the impulse therethrough, thereby to effect a predetermined exposure to the film irrespective of the density of the negative.

7. An electric system having, in combination, means for producing an electric-energy discharge impulse that would normally extend over a predetermined short interval of time, means for monitoring the output energy resulting from the application of the impulse to a load, and means connected with the monitoring means and actuable at the instant that the total energy monitored thereby has reached a predetermined value less than that which would have been produced by the electric-energy discharge impulse over the said predetermined time interval for thereupon terminating the application to the load of the electric-energy discharge impulse.

8. An electric system having, in combination, means for producing an electric-energy impulse that would normally extend over a predetermined short interval of time, means for delivering the impulse to a radiant-energy-producing load, means for monitoring the radiant energy of the load, and means connected with the monitoring means and actuable at the instant that the total energy monitored thereby has reached a predetermined value, less than that which would have been produced by the delivery to the load of the electric-energy impulse over the said predetermined time interval, for thereupon by-passing from the load the delivery of the impulse thereto.

9. An electric system having, in combination, means for producing an electric-energy impulse that would normally extend over a predetermined short interval of time, means for delivering the impulse to a radiant-energy-producing load, means including integrating apparatus for monitoring the radiant energy of the load, and means connected with the monitoring means and actuable at the instant that the total energy integrated thereby has reached a predetermined value, less than that which would have been produced by the delivery to the load of the electric-energy impulse over the said predetermined time interval, for thereupon short-circuiting the load.

10. An electric system having, in combination, means for producing an electric-energy impulse that would normally extend over a predetermined short interval of time, means for delivering the impulse to a radiant-energy-producing load, means for monitoring the radiant energy of the load and including integrating apparatus, a normally ineffective switching device controlled by the integrating apparatus and adapted to be rendered effective upon the integration of energy of predetermined value less than that which would have been integrated during the delivery to the load of the electric-energy impulse over the said predetermined time interval, and means responsive to the rendering effective of the switching device for thereupon short-circuiting the load.

11. An electric system having, in combination, means for producing an electric-energy impulse that would normally extend over a predetermined short interval of time, means for delivering the impulse to a radiant-energy-producing load, means for monitoring the radiant energy of the load and including integrating apparatus, a first normally ineffective switching device controlled by the integrating apparatus and adapted to be rendered effective upon the integration of energy of predetermined value less than that which would have been integrated during the delivery to the load of the electric-energy impulse over the said predetermined time interval, and a second switching device responsive to the rendering effective of the first switching device for thereupon short-circuiting the load.

12. An electric system having, in combination, means for discharging through a flash device an electric impulse that would normally extend over a predetermined interval of time to produce a predetermined quantity of light energy in the device, means for monitoring the light energy produced in the flash device, and means connected with the monitoring means and actuable at the instant that the total light energy monitored thereby has reached a predetermined value less than the said predetermined quantity for thereupon short-circuiting the flash device.

13. An electric system having, in combination, means for discharging through a flash device an electric impulse that would normally extend over a predetermined interval of time to produce a predetermined quantity of light energy in the device, means for monitoring the light energy produced in the flash device, means connected with the monitoring means and actuable at the instant that the total light energy monitored thereby has reached a predetermined value less than the said predetermined quantity for thereupon short-circuiting the flash device, and means for varying the said predetermined value.

14. An electric system having, in combination, means for discharging through a flash device an electric impulse that would normally extend over a predetermined interval of time to produce a predetermined quantity of light energy in the device, means for monitoring the light energy produced in the flash device and including integrating apparatus, a normally ineffective switching device controlled by the integrating apparatus and adapted to be rendered effective upon the integration of light energy of predetermined value less than the said predetermined quantity, and means responsive to the rendering effective of the switching device for thereupon short-circuiting the flash device.

15. An electric system having, in combination, means for discharging through a flash device an electric impulse that would normally extend over a predetermined interval of time to produce a predetermined quantity of light energy in the device, means for monitoring the light energy produced in the flash device and including integrating apparatus, a first normally ineffective switching device controlled by the integrating apparatus and adapted to be rendered effective upon the integration of light energy of predetermined value less than the said predetermined quantity, and a second switching device responsive to the rendering effective of the first switching device for thereupon short-circuiting the flash device.

16. An electric system having, in combination, means for discharging through a flash device an electric impulse that would normally extend over a predetermined interval of time to produce a predetermined quantity of light energy in the device, means for monitoring the light energy produced in the flash device and including integrating apparatus, a first normally ineffective gaseous-discharge switching device controlled by the integrating apparatus and adapted to be rendered effective upon the integration of light energy of predetermined value less than the said predetermined quantity, a second normally ineffective gaseous-discharge switching device of impedance, when effective, low compared to the impedance of the flash device during the discharge of the impulse therethrough, means for connecting the second gaseous-discharge device across the flash device, and means for rendering the second switching device effective upon the rendering effective of the first switching device, thereby thereupon to short-circuit the flash device.

17. An electric system as claimed in claim 16 and in which the monitoring means comprises photoelectric means and the integrating apparatus comprises an integrating network connected to control the rendering effective of the first gaseous-discharge switching device.

18. An electric system having, in combination, a flash device having a pair of principal electrodes and a trigger electrode, means for storing potential between the principal electrodes of value insufficient to discharge through the flash device except upon the application of a triggering impulse to the trigger electrode, whereupon the potential may be discharged through the flash device to produce a predetermined quantity of light, means for applying a triggering impulse to the trigger electrode, photocell means for monitoring the resulting light energy produced by the flash device, integrating means connected to the photocell means, a normally ineffective switching device controlled by the integrating means and adapted to be rendered effective upon the integration of light energy of predetermined value less than the said predetermined quantity, and means responsive to the rendering effective of the switching device for thereupon effectively short-circuiting the flash device.

19. An electric system having, in combination, a flash device having a pair of principal electrodes and a trigger electrode, means for storing potential between the principal electrodes of value insufficient to discharge through the flash device except upon the application of a triggering impulse to the trigger electrode, whereupon the potential may be discharged through the flash device to produce a predetermined quantity of light, means for applying a triggering impulse to the trigger electrode, photocell means for monitoring the resulting light energy produced by the flash device, integrating means connected to the photocell means, a first gaseous-discharge device biased to be normally non-conducting and connected to the integrating means to control the bias, means for adjusting the integrating means to a value such that upon the integration of light energy of a predetermined value less than the said predetermined quantity the bias upon the first gaseous-discharge device is such as to permit the gaseous-discharge device thereupon to become conductive, a second normally non-conductive gaseous-discharge device of impedance, when conductive, low compared to the impedance of the flash device during the discharge therethrough, means for connecting the second gaseous-discharge device across the flash device, and means controlled by the rendering conductive of the first gaseous-discharge device for thereupon rendering the second gaseous-discharge device conductive, thereby to short-circuit the flash device.

20. An electric system as claimed in claim 19 and in which the second gaseous-discharge device comprises an anode and a cathode connected to the principal electrodes of the flash device and a trigger electrode, and the last-named means comprises an energy-storing capacitor adaped to discharge through the first gaseous-discharge device upon the rendering conductive of the same in order to produce a trigger impulse for application to the trigger electrode of the second gaseous-discharge device, thereby to render the second gaseous-discharge device conductive.

21. An electric system as claimed in claim 12 and in which the flash-device is directed to transmit the light-energy through a negative and a lens to a film, and means is provided for directing part of the transmitted light energy to the monitoring means.

22. An electric system as claimed in claim 8 and having means for varying said predetermined energy value.

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Dedication

3,033,988.—*Harold E. Edgerton*, Belmont, Mass. METHOD OF AND APPARATUS FOR THE CONTROL OF ELECTRIC IMPULSES. Patent dated May 8, 1962. Dedication filed, Apr. 13, 1972, by the assignee, *Honeywell Inc.*

Hereby dedicates to the Public the remaining term of said patent.

[*Official Gazette September 12, 1972*]