

March 3, 1936.

P. E. STOGOFF

2,032,958

ENERGY TRANSLATING SYSTEM

Filed Nov. 11, 1931

2 Sheets-Sheet 1

Fig. 1.

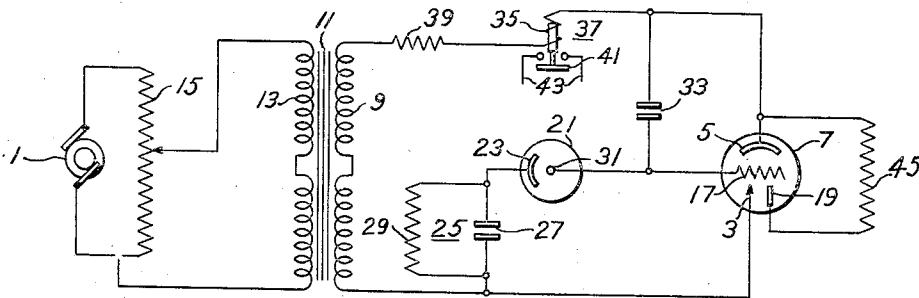
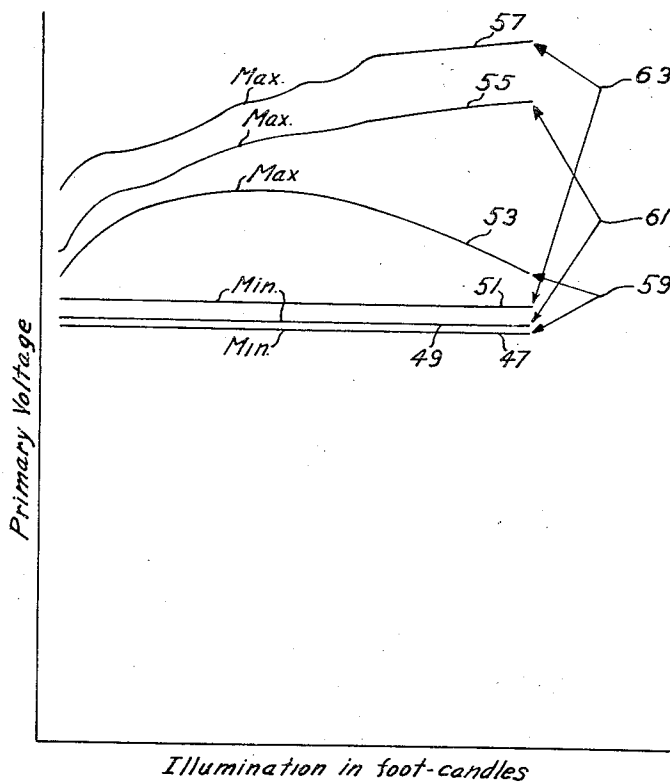


Fig. 2.



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Fig. 5.

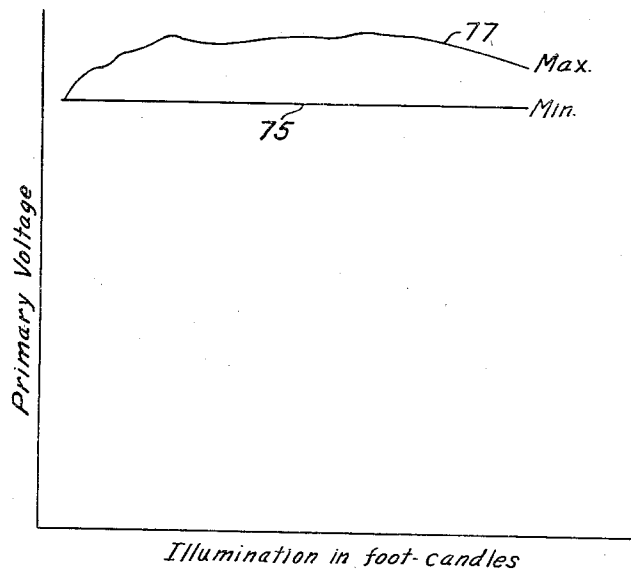


Fig. 4.

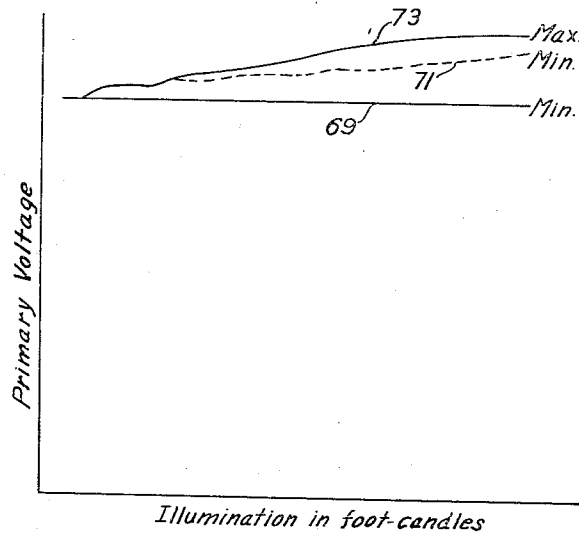
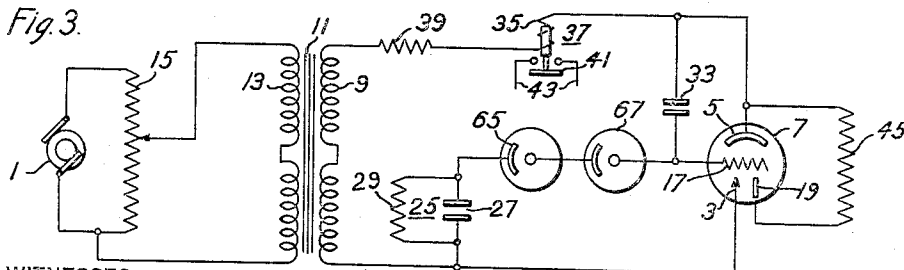


Fig. 3.



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ENERGY TRANSLATING SYSTEM

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Application November 11, 1931, Serial No. 574,345

2 Claims. (Cl. 250—41.5)

My invention relates to energy translating systems and has particular relation to relays wherein triggers of the photo-sensitive type cooperate with electric discharge devices to produce the necessary amplified effect.

In accordance with the teachings of the prior art a number of systems relating to my improved translating apparatus have been developed. In connection with electric discharge devices of the high vacuum type, such as the commonly known thermionic tubes, the practice in the past has been to connect a photo-sensitive device between the electrodes of the thermionic device in such manner that the polarity of the electrodes of the photo-sensitive device corresponds to the polarity of the electrodes of the electric discharge device.

Thus, in accordance with the teaching of the prior art when the control electrode of the electric discharge device is at a lower potential relative to the anode thereof than that of the cathode relative to the anode, the cathode of the photo-sensitive device may be connected to the control electrode of the electric discharge device and the anode of the photo-sensitive device may be connected to the cathode of the electric discharge device. In such a case an increase of illumination on the cathode of the photo-sensitive device produces an increase in the current transmitted by the electric discharge device, while a decrease in the illumination of the photo-sensitive cathode produces a decrease in the current transmitted by the electric discharge device.

Correspondingly, the cathode of the photo-sensitive device may be connected to the control electrode of the electric discharge device while the anode of the photo-sensitive device may be connected to the anode of the electric discharge device. In such a system the results of varying illumination are the same as in the system described hereinabove.

On the other hand if the electric discharge tube happens to be of a type in which the cathode is maintained at a lower potential than the control electrode, the photo-sensitive cathode is normally connected to the cathode of the electric discharge device and the anode of the photo-sensitive device is normally connected to the control electrode. In such a case an increase in the illumination impinging on the photo-sensitive cathode produces a decrease in the current transmitted by the electric discharge device and a decrease in the illumination impinging on the photo-sensitive cathode produces an increase in the current transmitted by the electric discharge device. In the following discussion I shall refer

to the circuit in which the thermionic current varies directly with the illumination of the photo-sensitive device as the direct system and to the circuit in which the thermionic current varies inversely with the illumination of the photo-sensitive device as the inverse system.

It is to be noted that even as far as thermionic tubes are concerned, the inverse system and the direct system are not the same as to sensitivity. In general, a gas filled photo-sensitive cell may be utilized with better success where high sensitivity is desired. However, it is to be remembered that a gas filled photo-sensitive cell, unlike a vacuum cell, has certain limitations with regard to the values of the illuminating flux and voltage that may be simultaneously impressed thereon. If the voltage and illuminating flux attain limiting values, a disruptive discharge takes place in the cell and unless the discharge is very quickly interrupted the cell is destroyed.

On the other hand the values of the capacities which necessarily exist between the control electrodes and the principal electrodes of an electric discharge device are not equal. Consequently, if a predetermined electromotive force is impressed between the principal electrodes of the device, the electromotive force will divide itself with regard to the control electrode and the principal electrodes in inverse relation to the values of the capacities between the control electrodes and the respective principal electrodes. That is to say, if an electromotive force of say several hundred volts is impressed between the principal electrodes of an electric discharge device and if the capacity between the anode and the control electrode, for example, is large compared to the capacity between the cathode and the control electrode, the greater fraction of the electromotive force will be impressed between the cathode and the control electrode.

Finally, it may be noted that in gas filled devices of the cold cathode type, in general, the voltage drop between the control electrode and cathode is great compared to the voltage drop between the anode and control electrode, since in tubes of this type, the cathode drop is considerably greater than the anode drop.

In general, the characteristics of the common photo-cells now on the market are so related to the characteristics of a number of the tubes now on the market that by reason of this difference in the capacities between the electrodes of the tubes, a gas filled cell can only be connected between the two electrodes between which the voltage is low and cannot with safety be con-

nected between the two electrodes between which the voltage is high. It is seen, therefore, that the sensitivity of the direct circuit may be entirely different from the sensitivity of the inverse circuit, the difference depending on the characteristics of the electric discharge device which is utilized.

This situation is particularly disadvantageous in connection with the use of a gas filled electric discharge device of the grid-glow type, for example, with a photo-sensitive device. The gas filled electric discharge device is abrupt in its characteristic and for a predetermined illumination of the photo-sensitive device associated with it, changes its character abruptly and becomes either conducting or non-conducting depending on the type of circuit which is utilized (i. e., direct circuit or an inverse circuit) on the polarity of variation of the illumination.

In gas filled devices, particularly of the grid-glow type, the control electrode is normally disposed very near to the anode. The adjacent disposition of the control electrode and the anode arises by reason of the fact that when these two electrodes are very near to each other a discharge does not take place between them even if considerable voltage is impressed between them. However, since these electrodes are near to each other and since the cathode is displaced a considerable distance from these electrodes, the capacity between the control electrode and the anode in an electric discharge device of this type is normally great compared to the capacity between the control electrode and the cathode. Consequently, if in such a system a photo-sensitive cell is connected between the control electrode and the cathode, the voltage impressed between the electrodes of the cell would be substantially equivalent to the voltage impressed between the principal electrodes of the electric discharge device and greater than the limiting voltage allowable for the ordinary photo-sensitive cell.

Again, the control electrode of a gas filled electric discharge device is normally maintained at a potential between the potentials of the principal electrodes and consequently by connecting a photo-sensitive device properly between these electrodes, an inverse circuit may be attained. In the direct system incorporating a gas filled electric discharge device, the photo-sensitive device is normally connected between the control electrode and the anode while in the inverse system the photo-sensitive device is normally connected between the cathode and the control electrode. In consequence of the structure of the gas filled device, it is possible to connect a gas filled photo-sensitive device in the direct circuit but it is impossible to connect a gas filled photo-sensitive device in the inverse circuit.

On the other hand the inverse circuit has a tendency of preserving the life of the tube since in such a system the tube is only energized when the relay is active. In systems where it is desirable that a photo-sensitive device be illuminated continually and be dark only when a certain contingency occurs, the inverse system is preferable to the direct system. Such a situation arises, for example, in connection with traffic control apparatus of the type in which photo-sensitive street devices are incorporated.

As explained hereinabove, if the inverse system is utilized in such apparatus and if the apparatus is constructed in accordance with the teachings of the prior art, the inverse system can only be utilized at a sacrifice of sensitivity.

It is accordingly an object of my invention to provide an inverse photo-sensitive system having a high sensitivity.

Another object of my invention is to provide an inverse photo-sensitive system incorporating a gas filled photo-cell.

A further object of my invention is to provide for a translating system incorporating an electric discharge device, a circuit of such character that a gas filled photo-sensitive device may be utilized regardless as to whether the system is direct or inverse in its operation and regardless of the capacitive relation between the electrodes of the electric discharge device.

A still further object of my invention is to provide for a translating system incorporating an electric discharge device, a circuit of such character that a gas filled photo-sensitive device may be utilized regardless as to whether the system is direct or inverse in its operation, and regardless of the distribution voltage between the electrodes of the electric discharge device.

A specific object of my invention is to provide a relay system incorporating a gas filled electric discharge device and a gas filled photo-sensitive device which shall have an inverse operating characteristic.

Another specific object of my invention is to provide a relay system incorporating a tube of the grid-glow type and a gas filled photo-sensitive device which shall have an inverse operating characteristic.

More concisely stated it is an object of my invention to provide a relay system incorporating an electric discharge device and a photo-sensitive device which shall be capable of direct or inverse operation with substantially the same sensitivity regardless of the mechanical and electrical characteristics of the electric discharge device and of the photo-sensitive device.

According to my invention I provide an inverse system in which the photo-sensitive cathode is connected to the anode of the electric discharge device and the anode of the photo-sensitive device is connected to the control electrode of the electric discharge device. While I have restricted myself to such a system in the present discussion, it is, of course, understood that my invention may be applied in a broader sense.

In a broad sense if any trigger device having the characteristic of emitting electrical particles of a predetermined polarity is associated with an asymmetric electric discharge device in which polarity is assigned to the electrodes of the device to produce a relay, in accordance with my invention the emitting electrode of the device responsive to physical influences is connected to the electrode of the electric discharge device which has a polarity opposite to the polarity of the particles emitted.

In experimenting with the more specific elements of my apparatus which are described herein, I have found that the operation of the system is considerably improved if an alternating current potential is impressed between the principal electrodes of the electric discharge device. I have also found that the operation of the system is improved if a capacitor or other energy storing system is connected between the other electrodes of the electric discharge device.

As to the operation of the system, it is my present opinion that the negative charges emitted by the photo-sensitive cathode probably charge the capacitor during the half-cycle of the alternating wave, impressed between the electrodes

during which the anode of the electric discharge device is negative and the cathode of the electric discharge device is positive. During the other half-cycle, the photo-sensitive device probably acts as a locked valve and does not permit the negative charge to leak away from the capacitor or from the control electrode.

On the other hand the characteristics of the circuit are always such that a considerable difference of phase exists between the voltage applied to the principal and the voltage applied between the electrodes of the photo-sensitive device. Consequently, while the voltage impressed between the principal electrodes of the electric discharge device passes through zero, and the anode becomes positive and the cathode negative, the voltage impressed between the electrodes of the photo-sensitive device remains negative for a predetermined interval. The control electrode of the electric discharge device thus remains negative when the change in polarity of the principal electrodes takes place. In accordance with my theory, the phase difference between the two voltages is probably of the order of 180° , or at least is so great that the proper values of voltage impressed between the control electrode and the anode, and between the anode and the cathode do not coincide to produce a discharge.

In consequence of the flow of negative charges during the half cycles, the control electrode is normally maintained at a high negative potential and a discharge between the cathode and the anode of the electric discharge device is prevented as long as the photo-sensitive device is illuminated. However, if the illumination of the photo-sensitive device is sufficiently decreased, the negative charges are no longer supplied to the control electrode and the electric discharge device becomes energized.

It is to be noted that the effect of the photo-sensitive device is the same if an electric discharge device of the gas filled type is utilized as it is for a device of the high vacuum type. In the latter case, the negative charge supplied by the excited photo-sensitive device simply exercises a repulsive force on the negative charge supplied on the hot cathode and consequently decreases the current in the device. In the former case the negative charges supplied by the photo-sensitive device interact with the ions in the gas filled device to prevent the passage of current as long as the photo-sensitive device provides sufficient negative charge.

It is again to be noted that while I regard my explanation as a reasonable one, I do not wish to be restricted in any way by it.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which.

Figure 1 is a diagrammatic view showing a circuit constructed in accordance with my invention;

Fig. 2 is a graph showing the limitations of various photo-sensitive devices utilized in the practice of my invention;

Fig. 3 is a diagrammatic view showing a modification of my invention; and

Figs. 4 and 5 are graphs showing the advantages, in certain connections, of a system such

as is shown in Fig. 3 over a system such as is shown in Fig. 1.

The apparatus shown in Fig. 1 comprises an alternating current power supply source 1 where-by an alternating voltage is impressed between the principal electrodes 3 and 5 of an electric discharge device 7 through the secondary 9 of a transformer 11, the primary 13 of which is in turn fed from a potentiometer 15 connected directly across the power supply source 1.

The electric discharge device 7 utilized in the preferred practice of my invention is a tube of the grid-glow type incorporating in addition to the principal electrodes 3 and 5, a control electrode 17 and a shielding electrode 19. The purpose of the shielding electrode 19 bears no relation to the present invention and it will consequently not be discussed herein.

While I have shown in the preferred embodiment of my invention, an electric discharge device of the gas filled type and of the cold electrode type I do not wish to be restricted to such a device. As has been explained hereinabove it may be practiced equally as well with a gas filled device of the hot cathode type or with a high vacuum electric discharge device in certain connections. It may also be utilized with electric discharge devices incorporating cathodes or other excited cathodes.

The photo-sensitive device 21 utilized in the practice of my invention is preferably of the gas filled type and its photo-sensitive element 23 is connected to the anode 3 of the electric discharge device 7 through a circuit 25 having a predetermined time constant and incorporating a capacitor 27 and a resistor 29. The anode 31 of the photo-sensitive device 21 is connected to the control electrode 17 of the electric discharge device 7 and a second capacitor 33 is preferably connected between the cathode 5 of the electric discharge device 7 and its control electrode 17.

The phase difference between the voltage applied to the principal electrodes of the electric discharge device and the voltage applied to the electrodes of the photo-sensitive device is probably introduced by the capacitor 33 principally and by the other capacity effects present in the circuit.

I have also found that the capacitor 27 and resistor 29 connected between the photo-sensitive cathode 23 and the anode 31 of the electric discharge device 21 have an important bearing on the operation of the system and determine, for example, the characteristics of the system with regard to the variation in illumination which is necessary to cause its operation. However, I wish it to be clearly understood that the time constant circuit 25 is not a sine qua non of the system and I have as a matter of fact found that the system is satisfactorily operative if the capacitor 27 is admitted or if the time constant circuit is replaced by an impedance of any general type.

The principal circuit of the electric discharge device 7 feeds the exciting coil 35 of a relay 37 through a current limiting resistor 39 of a predetermined value. The contactor 41 of the relay 37 is responsive to the variation in current in its exciting coil and under the proper conditions closes a circuit 43 which is provided for the purpose of operating the system which is to be controlled by the relay.

For purposes which need not be discussed herein, the shielding electrode 19 is connected to the cathode 5 of the electric discharge device 7 through a suitable impedance 45.

I have found that a satisfactorily operative system may be provided by utilizing a cold electrode grid-glow tube of the type in which 440 volts is impressed between the cathode 5 and the anode 3. In such a system, the current limiting impedance 39 is of the order of 14,500 ohms, the resistance 29 of the time-constant circuit 25 is of the order of .87 megohm, the capacitor 27 of the time constant circuit 25 is of the order of .000025 microfarad, the capacitor 33 connected between the control electrode 17 and the cathode 5 of the electric discharge device 7 is between 5 and 50 microfarads and the resistor 45 connected between the shielding electrode 19 and the cathode 5 is .87 megohm.

In Fig. 2, curves are plotted showing the limitations between which certain photo-cells which were available to me are operated. The voltage plotted as ordinate and designated as "primary voltage" was $\frac{1}{2}$ of the voltage impressed between the principal electrodes 3 and 5 of the electric discharge device 7. The illumination which was projected on the photo-sensitive cathode 23 of the device 21 is plotted as abscissa. The curves 47, 49 and 51 designated as "min." bound the region below which the system failed to respond. The curves 53, 55 and 57 designated as "max." bound the region above which the photo-sensitive device glowed. The connected arrows 59, 61 and 63 shown on the graph point respectively to the pairs of curves which relate to the same tubes.

When an electromotive force less than approximately 264 volts was impressed between the cathode and the anode of the electric discharge device of the type to which curves 47 and 53 relate, the system failed to operate entirely regardless of the illumination impressed on the photo-sensitive cathode. On the other hand, if an illumination of 40 foot candles, for example, was impressed on the cathode of the same tube and at the same time the electromotive force impressed between the cathode and the anode of the electric discharge device was raised above 352 volts, a disruptive discharge occurred in the tube and if this discharge continued for a considerable time, the tube was destroyed.

It is to be noted that the same tube would not be applicable at all in a system in which the photo-sensitive device is connected between the cathode and the control electrode of the electric discharge device.

In the modification of my invention shown in Fig. 3, substantially the same elements are incorporated as are shown in the preferred embodiment. However, instead of one photo-cell, two photo-cells 65 and 67 are connected between the control electrode 17 and the anode 3. It is to be noted that in this modification of my invention the two photo-cells are symbolical of any number of photo-cells which may be connected in the same manner.

Figs. 4 and 5 which are graphs to a large extent similar to Fig. 2, show the advantage which a system such as is shown in Fig. 3 might, in certain connections, have over a system such as is shown in Fig. 1. In Fig. 4 the bounding curves 69, 71 and 73 for the region of applica-

bility of two photo-sensitive devices, when utilized in a system such as is shown in Fig. 1, is plotted.

In Fig. 5 the bounding curves 75 and 77 for the same two photo-sensitive devices incorporated in a system such as is shown in Fig. 3 and operated as a unit, are plotted. It will be noted that the area under the curves shown in Fig. 5 is considerably greater than the area under the curves shown in Fig. 4. Consequently, in certain connections it may be of advantage to increase the range of applicability of a particular set of photo tubes by connecting them in series in the system.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and the spirit of the appended claims.

I claim as my invention:

1. Energy translating apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, said principal electrodes having structures of a type to render said electric discharge device asymmetric in its electrical conductivity in such manner that when one of said principal electrodes has a predetermined electrical polarity relative to another of said principal electrodes, said electric discharge device passes substantial current, means for impressing an alternating potential between said principal electrodes, a single electric discharge device of a type having at least principal electrodes, one of said electrodes to emit electrical particles of a predetermined polarity when subjected to the influence of a physical disturbance, means for connecting said emitting electrode of said last-named electric discharge device, to the electrode of said first-named electric discharge device that has a polarity opposite to the polarity of said particles when said first-named electric discharge device passes substantial current, means for connecting another of said electrodes of said last-named device to said control electrode of said first-named electric discharge device and means for storing electric charges connected between said control electrode and another of said electrodes of said first-named electric discharge device.

2. Energy translating apparatus comprising an electric discharge device having an anode, a cathode and a control electrode, the inter-electrode capacity between said control electrode and said anode being large in comparison with the inter-electrode capacity between said control electrode and said cathode, means for impressing an alternating potential between said anode and said cathode, a photo-sensitive device of the type incorporating an anode and a cathode immersed in a gaseous medium, means for connecting the anode of said photo-sensitive device to said control electrode, means for connecting the cathode of said photo-sensitive device to the anode of said electric discharge device and charge-storing means connected between the control electrode and the cathode of said electric discharge device.

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