

April 16, 1929.

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1,709,763

LIGHT RESPONSIVE RELAY

Filed Oct. 15, 1926

2 Sheets-Sheet 1

Fig. 1.

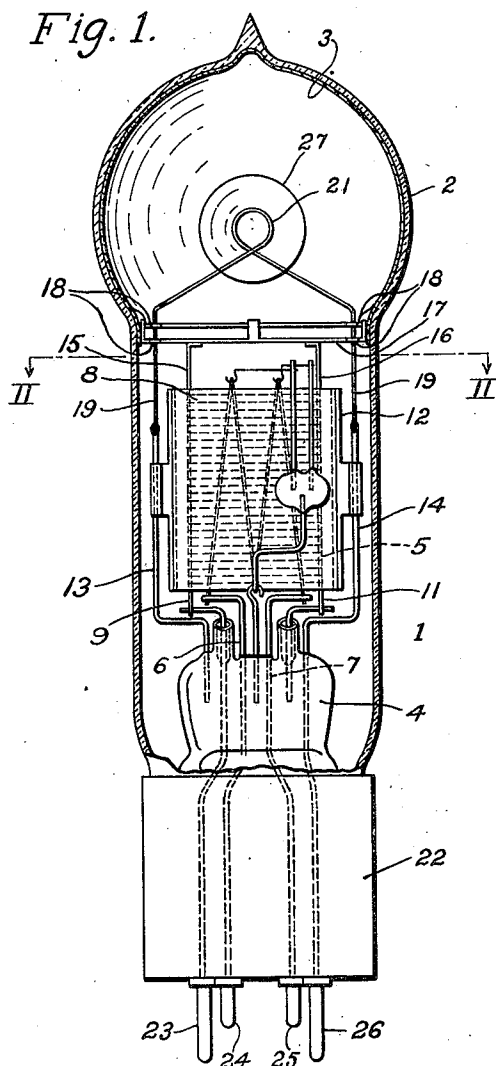
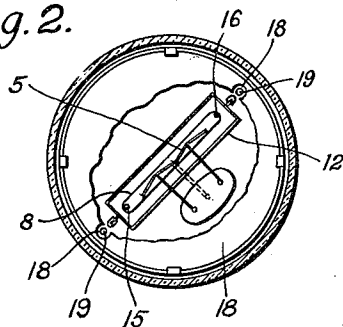


Fig. 2.



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2 Sheets-Sheet 2

Fig. 3.

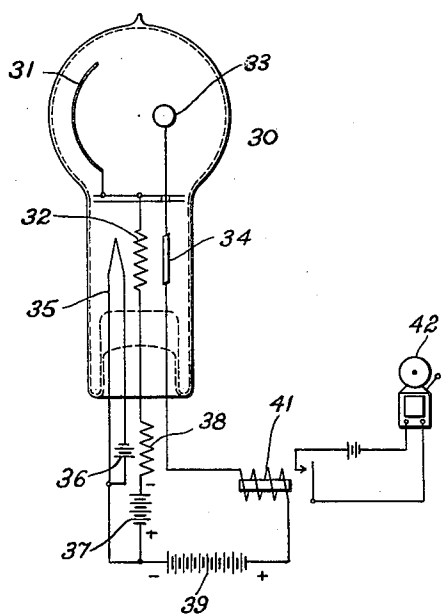


Fig. 4.

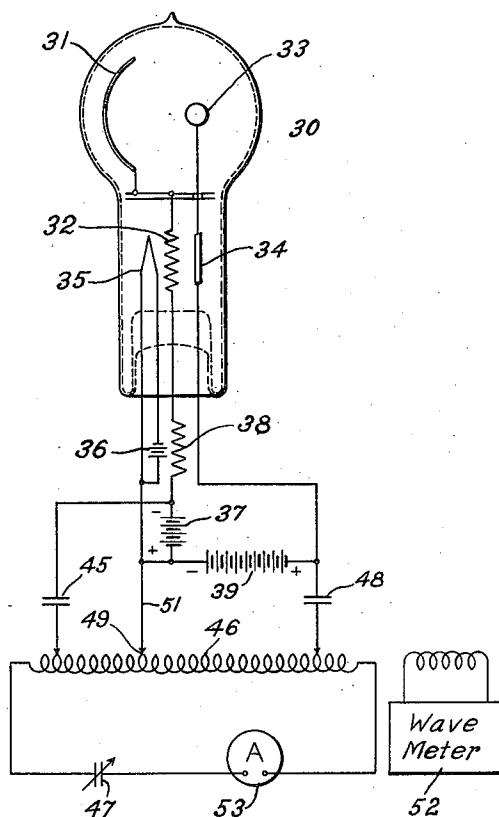
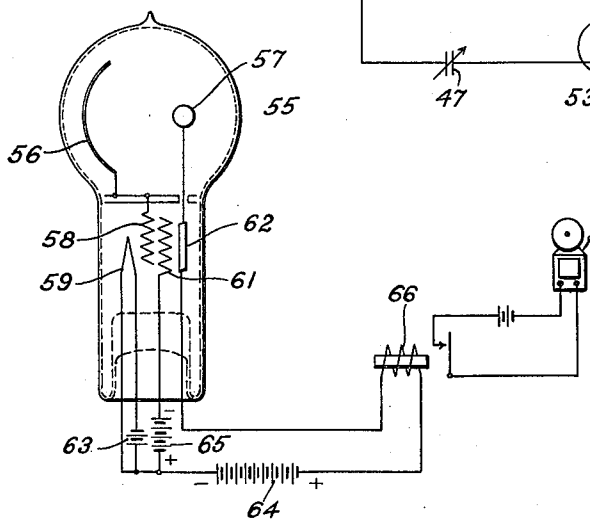


Fig. 5.



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LIGHT-RESPONSIVE RELAY.

Application filed October 15, 1926. Serial No. 141,734.

My invention relates to light-responsive relay systems, and more particularly to systems in which a photo-electric cell is utilized to control the output of a thermionic amplifier.

One object of my invention is to provide a relay system in which the time lag is inappreciable.

Another object of my invention is to provide, in one unitary device, a photo-electric cell and a thermionic amplifier.

Another object of my invention is to provide a system of circuit connections whereby the numerous advantages of my improved photo-cell thermionic-amplifier may be fully utilized.

Still other and more specific objects will later be explained.

In my applications Serial No. 43,220, filed July 13, 1925, and Serial No. 43,221, filed July 13, 1925, I have disclosed and claimed certain specific forms of combined photo-electric cells and thermionic amplifiers, together with circuits peculiarly adapted thereto. My present invention relates generically to both of the applications referred to and is in the nature of an improvement thereon.

In practicing my invention, I may utilize substantially any thermionic amplifier tube of a conventional design, so modifying the glass portion thereof as to accommodate a photo-electric cell, and providing means whereby the several portions of the device are effectively isolated one from another.

The novel features which are considered characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawings, in which

Fig. 1 is a view, partly in elevation and partly in section, of a preferred form of my invention,

Fig. 2 is a sectional view taken along a line corresponding to the line II—II of Fig. 1,

Figs. 3 and 4 are diagrammatic views of circuit connections for utilizing my invention, and

Fig. 5 is a diagrammatic view of an alternative form of my invention.

Referring to Figs. 1 and 2, I will now describe the manner in which my improved photo-electric device is constructed. A cylindrical glass envelope, having, at one end, a semi-spherical enlarged portion 2, may be first treated so that a deposit of conducting material, such as platinum, is formed on the inner surface 3 of the semi-spherical portion.

A press 4, on which are mounted the usual elements of a thermionic tube and certain additional elements required by my invention, is then inserted into the cylindrical portion of the glass envelope and sealed in place. The elements mounted on the press 4 comprise a filament 5 carried by standards 6 and 7, a grid 8 wound on standards 9 and 11 and an anode 12 mounted on standards 13 and 14 fixed in the press.

The grid standards are provided with upwardly extending portions 15 and 16, which support a circular, double-wall metallic partition 17, slightly less in diameter than the cylindrical portion of the envelope. The partition 17 is provided with openings 18 through which project the ends of a continuous conductor 19 affixed to, and rigidly supported from, the anode standards 13 and 14. The central portion of the conductor 19 is provided with a loop 21 which serves as a collector-electrode.

On inserting the press 4 and the elements carried thereby into the glass envelope, care is taken to see that the partition 17 is fixed at the portion of the envelope where the enlargement 2 begins, and that the looped portion 21 of the conductor 19 lies at the approximate focus of the enlarged portion.

The assembled device is cemented into a base 22 provided with a plurality of contact elements 23, 24, 25 and 26 to which leads from the grid, filament and anode, are soldered, as is customary in the manufacture of the thermionic tubes of the usual types. The contact elements may be asymmetrical, or may be dissimilar in size, if desired, in order to obviate the possibility of wrongly inserting the device into a cooperating socket. At the points where the grid-leads emerge from the press, they are surrounded, for a short distance, by tubular extensions of the press-material, with the inner surfaces of which the said leads do not make contact. A long leakage path is thus provided between the grid leads and the leads connected to the anode and the filament.

The entire device is then heat-treated and exhausted according to any of the customary methods, and a small amount of potassium is so distilled into the enlarged portion as to
5 cover the conductive coating previously deposited on the interior surface thereof and also make contact with the double-walled partition 17. A small area 27 of the enlarged
10 portion 2 may then be heated, causing re-distillation of the potassium, in order to provide a window through which light may enter the cell.

Instead of potassium, I may utilize other metals or alloys, for instance, an alloy of potassium and barium, as the photo-electric substance. If potassium, or an alloy thereof is employed, sensitivity of the deposit may be increased, by filling the bulb with pure hydrogen at a pressure of 1 mm. of mercury, and
20 then passing a direct current discharge between the alkali layer and the collector, using the layer as the cathode. After this treatment, the bulb is re-exhausted.

During the second exhausting, it is preferable that all tubing connecting the device with the distillation chambers be heated to drive off all occluded hydrogen.

It has been found extremely important to thoroughly purify the hydrogen employed
30 for the sensitizing process, as well as the argon used in a gas filled photo-cell. Unless precautions are taken to have the hydrogen and argon absolutely pure, the sensitive cathode gradually deteriorates in use, losing
35 the characteristic blue color indicative of extreme sensitivity.

The purification method I have found preferable for hydrogen is as follows: The commercial hydrogen, as received from the
40 makers, is first thoroughly dried by passing it through a liquid air trap. It is then led into a large glass container in which are positioned a plurality of tungsten electrodes. An electric arc is then passed between the electrodes, and any oxygen which may contaminate the hydrogen is caused by the arc to combine with a portion of the hydrogen to form water. The water resulting from this treatment is absorbed by phosphorous pentoxide which may be retained in the bottom of the large container in which the purification takes place, or may be positioned in a separate chamber through which the hydrogen is caused to flow.

55 In this process of purification, it is highly important that the arc be kept continuously in operation, as its cessation permits a re-contamination of the formerly purified hydrogen.

60 The purification of argon is essentially the same, except that the electrodes must be made of calcium or sodium.

The partition, in addition to serving as a connection between the photo-electric substance and the grid of the thermionic portion

of the device, also functions to effectively isolate the photo-cell portion from the heat and light evolved from the filament when the device is in use.

It will be noted that only a single press is utilized for the support of one of the photo-cell elements as well as all of the thermionic-tube elements and that this press is located at a comparatively great distance from the photo-electric cell. By reason of this construction, and also by reason of the fact that the press is to some extent shielded from the potassium vapor by the inter-position of the anode and the partition, leakage between the elements of the photo-electric cell is reduced to a negligible quantity. It is also evident that the lower portion of the device will be warmer than the upper portion when the device is being used, which causes metallic vapors, if present, to rise and deposit in the cooler photo-electric cell portion.

By reason of the shortness of the connections between the photo-electric elements and the elements of the thermionic tube, the time-lag of my improved device is extremely short, much shorter in fact than is necessitated by present day commercial requirements. The device is accordingly, well adapted for use in connection with picture-transmission systems, fire or smoke detection, automatic inspection of manufactured or natural products, or in any system wherein an instantaneous response to varying light conditions is desired.

In Figs. 3 and 4, I have shown diagrammatically two possible systems for the utilization of my device, the system of Fig. 3 being designed for relay operation and that of Fig. 4 being adapted to give either a visual or an audible indication of changing light conditions or for wireless transmission of light signals.

Referring specifically to Fig. 3, a device 30, such as previously described, provided with a photo-electrically active mirror 31 connected to a grid, and a collector electrode 33 connected to an anode 34, has a filament 35 energized from a source 36 of low potential. A grid-biasing battery 37, preferably giving a potential of approximately 45 volts, is so connected through resistor 38 as to impress a sufficiently high negative potential upon the grid 32 to prevent the flow of thermionic current between the filament and the anode. The resistor may have a value of twenty megohms, approximately.

A source 39 of high potential (approximately two hundred and fifty volts) is connected through a relay winding between the anode 34 and the filament 35.

By properly choosing the anode-potential source and the grid-bias source, the system may be so adjusted that substantially no thermionic current will flow if the photo-electric cell portion is in darkness. The negative po-

tential on the grid is also so high that no electrons from the filament can reach the grid and alter the normal charge therein.

While light is falling on the photo-electric substance, the photo-electrons are expelled from it and, since the "B" and "C" batteries are connected in series-aiding relation in so far as the potential impressed between the photo-electric cathode and the collector is concerned, they arrive at the collector under acceleration of both of said batteries. This produces a flow of current which passes through the resistance 38, and produces a voltage drop across this resistance. The voltage drop alters the potential of the grid and permits a thermionic current to flow between the anode and the filament. The flow of current to the anode may be utilized to actuate the relay 41, in order to ring a bell 42, or energize other indicating apparatus.

It is interesting to note at this point that both the grid-biasing potential source and the anode-potential source are series-aiding, in so far as the photo-electric current is concerned, increasing the potential available for causing electronic emission from the mirror when subjected to light.

The device will function without the resistor 38 and the bias battery but not so satisfactorily as when they are included.

Referring to Fig. 4, this illustrates diagrammatically a system wherein my improved photo-electric amplifier may be utilized as an oscillation generator. The device per se is the same as that shown in Fig. 3, but, instead of utilizing a relay winding in the anode circuit, the grid 32 is coupled by a condenser 45 to an oscillating circuit comprising an inductor 46 and a condenser 47, and the anode 34 is also coupled to the same circuit through a condenser 48. An intermediate point 49 on the inductor is connected to the filament 35 by a conductor 51, in a manner analogous to the connections for the well known Hartley oscillation generator.

The grid-bias potential source and the anode potential source are so chosen that the circuit will not oscillate when the photo-electric tube portion is in darkness. Upon illumination of the photo-electric element, an electron discharge occurs between it and the target electrode 33. This photo-electric current causes a drop in potential in the resistor 38 and lowers the potential of the grid sufficiently, with respect to the filament, that a thermionic current is permitted to flow between the filament and the anode. Such a flow of current initiates oscillations in the oscillatory circuit comprising the inductor and the condenser, in a manner now well known to those skilled in the art. The oscillations will persist just so long as the photo-electric current flows under the influence of light and will cease upon the cell being darkened. The grid-bias may also be so adjusted

that the circuit will oscillate continuously, in which case, a variation of illumination of the photo-electric substance will cause a change in frequency of the oscillations. A wave meter 52 or analogous device may be coupled to the inductor 46 in order to give an indication of the presence therein of an oscillating current, or an ammeter 53 may be connected in series therewith for the same purpose.

The oscillating current may also be utilized to energize an antenna or other radiation circuit, either direct or through a power amplifier, thus providing a system which may be adapted to convey to a distant point an indication of changing light conditions at the location of the transmitter. Such a system would probably be of service in connection with forest fire prevention, or for analogous purposes, such as picture transmission.

During certain of my experiments with photo-cells of the type thus far referred to, I found that, in many cases, the resistor included in the grid circuit caused a very slight amount of time lag. The time lag, while negligible, in so far as present day requirements are concerned, might become of importance in connection with future developments in picture transmission, and I have accordingly developed an alternative form of my invention in which the lag is so slight that it is substantially not capable of being measured. The alternative form is shown diagrammatically in Fig. 5, and it will be noted that neither a resistor nor a grid-biasing battery is employed therewith.

Referring specifically to Fig. 5, a photo-electric amplifier 55, constructed substantially the same as the device illustrated in Fig. 1, comprises a photo-electrically active cathode 56, a co-operating collector-electrode 57 at the focus thereof, a thermionic portion comprising a grid 58 connected to the cathode 56, a filament 59, a second grid 61 interposed between the first grid and the filament, and an anode 62. For efficient operation, the capacity of the cathode-grid assembly to the filament should be extremely small. External connections are provided for the collector-anode assembly, the filament, and the extra grid 61. Structurally, the device is substantially the same as that illustrated in Fig. 1, except for the inclusion of the extra grid, and, for that reason, it is not considered necessary to more specifically illustrate it.

A source 63 of filament potential is provided, as well as a source 64 of anode potential and a source 65 for maintaining the second grid 61 at a positive potential relative to the filament. The second grid is analogous to the space-charge controlling grid referred to in U. S. patent to Schottky No. 1,537,708. As explained in the patent, when a thermionic tube is provided with a space-charge-control grid, it is possible to obtain a relatively large anode, or output, current with but relatively

low anode potential. The space-charge-control grid has also the very useful function of reducing the effective capacity between the anode and the input grid, which reduction of capacity also lessens the time elapsing between the input electrode potential changes and the accompanying changes in the output current. The lowered anode potential is also advantageous, as it lessens the likelihood of inter-electrode leakage.

In the operation of the form of my invention in which the thermionic tube is provided with two grids, the grid connected to the photo-electric cathode, being disconnected from any other portion of the circuit or device, assumes a definite negative potential dependent upon the illumination of the cathode and the number of electrons reaching the grid from the filament. The anode potential and the potential of the space-charge grid may be so adjusted that the normal potential which the floating grid assumes, the photo-cell being in darkness, is sufficient to block the tube. Upon illumination of the photo-electric cathode, electrons pass therefrom to the collector-electrode, thus leaving the grid more positive with respect to the filament. A thermionic current is accordingly permitted to flow between the anode and the filament, which current may be utilized to operate a relay 66 or an equivalent device.

A photo-electric device constructed according to my invention has numerous advantages over the devices of the prior art. All important connections are short and direct, and are protected against insulation leakage, inductive charges and breakage. By directly connecting the photo-electric cathode to the control grid I have provided a device in which the thermionic response is substantially instantaneous, rendering my device peculiarly adaptable to systems in which a time lag is detrimental.

Although I have illustrated and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible, and my invention is not to be limited except in so far as is necessitated by the prior art and as indicated by the appended claims.

I claim as my invention:

1. In combination, a container, photo-electric cell elements in one portion of the container, thermionic amplifier elements in another portion of the container, and a partition comprising a plurality of space separated portions interposed between the cell elements and the amplifier elements.

2. In combination, a container, photo-electric cell elements in one portion of the container, thermionic amplifier elements in another portion of the container, a partition interposed between the cell elements and the amplifier elements, one of the cell elements

being conductively connected to the partition.

3. In combination, a container, photo-electric cell elements including a photo-electrically active-electrode in one portion of the container, thermionic amplifier elements including a grid in another portion of the container, a partition interposed between the cell elements and the amplifier elements, said grid and said electrode being conductively connected to the partition,

4. In combination, a container, photo-electric cell elements including a collector-electrode in one portion of the container, thermionic amplifier elements including an anode in another portion of the container, a conductive partition interposed between the cell elements and the amplifier elements, and a connection between said electrode and said anode, said connection passing through but out of contact with said partition.

5. In combination, an elongated container having a cylindrical portion and a semi-spherical portion, a photo-electrically active element deposited on part of the interior surface of the semi-spherical portion, thermionic elements including a grid in the cylindrical portion, a partition between the cylindrical portion and the semi-spherical portion, and conductive connections between the grid, the photo-electrically active element, and the partition.

6. In combination, a container, photo-electric cell elements in one portion of the container, thermionic amplifier elements including a filament in another portion of the container, and shielding means interposed between said portions for preventing radiant energy from the filament from effecting the operation of the photo-electric cell.

7. In combination, a container, photo-electric cell elements in one portion of said container, thermionic amplifier elements in another portion of the container, a partition interposed between the cell elements and the amplifier elements, and means whereby the partition is supported from one of the amplifier elements.

8. In combination, a container, photo-electric cell elements in one portion of said container, thermionic amplifier elements comprising a filament, an anode and two grids in another portion of said container, a partition interposed between the cell elements and the amplifier elements, a conductive connection from one of said grids to said partition, and a conductive connection from one of said cell elements to said partition.

9. In combination, a container, thermionic amplifier elements in one portion of said container, a light sensitive element in another portion of the container, a partition interposed between the two portions of the container, the light-sensitive substance contacting with said partition, and a connection

from an amplifier element to said partition.

10. In combination, a container, thermionic amplifier elements including a grid in one portion of said container, a light sensitive element in another portion of the container, a conductive connection between said light sensitive element and said grid, the light-sensitive element and grid assembly having negligible capacity with respect to the remaining amplifier elements.

11. In combination, a container having an upper portion and a lower portion, photo-

electric cell elements in the upper portion, thermionic amplifier elements in the lower portion, and a partition having heat-insulating properties interposed between said portions; whereby the heat released in the lower portion when the device is in operation is largely prevented from being communicated to said upper portion.

In testimony whereof, I have hereunto subscribed my name this 2nd day of October, 1926.

VLADIMIR K. ZWORYKIN.