Oct. 30, 1934. A. W. HULL 1,979,226

LIGHT SENSITIVE APPARATUS

Original Filed Sept. 19, 1928

Fig. 1.

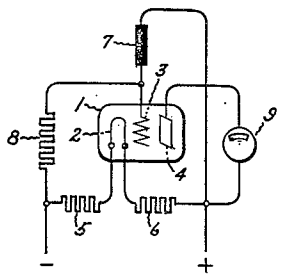


Fig. 2.

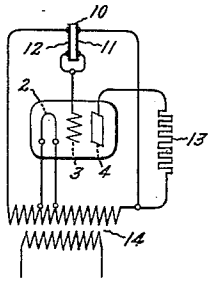
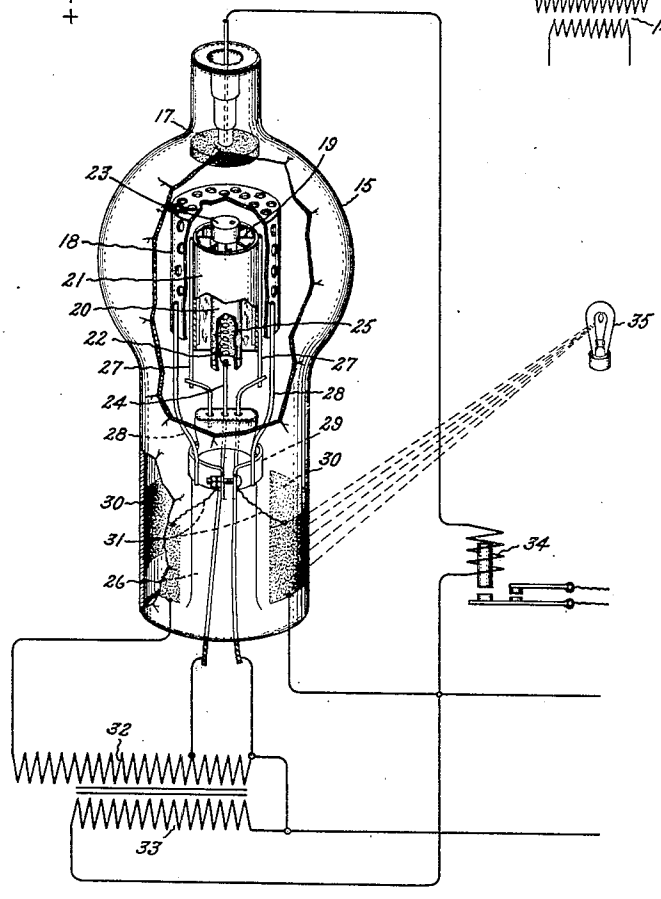


Fig. 3.



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LIGHT-SENSITIVE APPARATUS

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Original application September 19, 1928, Serial No. 306,945. Divided and this application August 25, 1933, Serial No. 686,749

5 Claims. (Cl. 250—27.5)

The present application constitutes a division of my application Serial No. 306,945 filed September 19, 1928, and entitled "Light-sensitive apparatus".

The invention has for an object the provision of an improved light-sensitive device capable of handling relatively large currents but which nevertheless, has sensitivity of control sufficiently delicate to respond faithfully to changes in a light source.

A further object of the invention is to provide a light-sensitive device of the selenium type which is protected from moisture effects and is compensated for ambient temperature changes.

Other objects and features will be apparent as the specification is perused in connection with the accompanying drawing in which Fig. 1 is a diagrammatical view of the system embodying some of the features of the invention including an electron discharge device and a single light-responsive member; Fig. 2 shows the application of the invention to a system employing alternating current and including two light-sensitive bodies combined into a single unit while Fig. 3 represents the combination of a large power amplifier together with light-responsive apparatus.

Referring to Fig. 1, numeral 1 designates the ordinary form of three-electrode thermionic device comprising a cathode 2, grid or control member 3, and a plate or anode 4. The cathode and plate circuits are energized from a source of current, shown as direct but which may equally well be alternating. In the event the source of energy is of commercial voltage, it is necessary to provide a voltage reducing arrangement for energizing the filament 2, which arrangement may comprise resistances 5 and 6, preferably of equal value, arranged on both sides of the filament and shunted across the line as shown. Between the grid and plate members, there is connected a device 7, the resistance of which changes in response to variations of a light source (not shown). The device 7 conveniently may take the form of a selenium cell or a block or insulation coated in any well-known manner with selenium or other substance, for example, molybdenite, the resistance of which changes in accordance with light variations. A resistance 8 is connected between the negative terminal of the source and the grid member 3. This resistance may have either one of two values depending upon the condition of the device 7 when the circuit is not operating and the change in that condition when current through the circuit is initiated by the light source. For example, if it is desired to operate the system from a dark condition of the selenium to an activated condition, the magnitude of resistance 8 should be comparable to that of the device 7 when the latter is in an inactivated or darkened state. On the other hand, if there is normally a light impinging on the member 7 and it is desired to register variations in that light as when comparing light intensities, the magnitude of the resistance 8 should be comparable to that of the device 7 when the latter is activated by the light of normal or standard intensity.

It is apparent that the system operates on the balanced bridge principle wherein current flows from the positive side of the line through the member 7 to charge the grid 3 positively. Current also passes through resistance 8 to charge the grid negatively. When these charges are equal, the potential of the grid 3 undergoes substantially no net change from the normal residual negative charge produced by the accumulation of electrons derived from the filament. However, when the magnitude of the resistance 7 is changed by the impingement of light, the balance of the bridge is destroyed and the positive charge transported to the grid preponderates over that of the negative charge causing substantial current to flow through the load 9 illustrated in the form of an ammeter. The ammeter may be useful in comparing two light intensities which successively activate the light-sensitive member 7 although the load may also comprise a sensitive relay for controlling external circuits for any suitable purpose, for example, switching on or off street or sign-board lights at appropriate times depending upon the amount of daylight present. In the event selenium is employed as the resistance-changing body, the circuit would have application to the control and regulation, by suitably designed relays, of an oil or coal self-firing furnace, the glow of which may contain considerable amounts of red light waves to which selenium is particularly responsive. Whatever be the function assigned to the circuit, it is apparent that I have disclosed an extremely sensitive arrangement which responds readily to slight changes in the resistance of device 7, faithfully reproducing the undulations derived from the light source in terms of an electric current flowing through the load. In the event that alternating current is utilized for the source of energy, current flow between the anode and cathode may be established only when the anode is positive with respect to the cathode, in which case, the instantaneous polarities of the source of energy

under operating conditions, necessarily will be the same as that shown and described.

Alternating current offers some advantages as a source of supply energy in that the voltage reducing arrangement may comprise a transformer instead of resistances 5 and 6. This arrangement has been exemplified in Fig. 2 which in addition, provides a constant resistance light-sensitive member, for example, a selenium cell in a permanently darkened or lighted condition in place of the resistance 8 of Fig. 1. The selenium cells may then be combined on a common block of insulation 10, the two coatings 11 and 12 being in thermal conducting relation with one another so that changes in the ambient temperature affect the two coatings equally thereby offering greater accuracy between the changes of space current and the light variations. It is evident that the variable light source should activate only one of the coatings 11 and 12, the inactivated coating being shielded as far as practical from the effects of the variable light. As in the case of Fig. 1, a balance may be obtained in the circuit and a normal negative charge be allowed to accumulate on the grid 3 by collection of electrons slightly in excess of that at which a plate current would be initiated so that when the selenium coatings are activated unequally as when the light falls on coating 11 while coating 12 remains in the dark or inactivated, grid 3 assumes a positive charge with the result that the filament-plate impedance is materially reduced and space current flows through load 13 represented as resistance. The initial balance may be obtained in any suitable manner, for example, by adjusting the position of the filament taps along the secondary of the transformer 14; obviously this adjustment should be such as to produce the maximum degree of sensitivity of the system in response to the light changes which condition usually is obtainable when the bridge is balanced.

Fig. 3 illustrates the application of the invention to a power amplifying tube, as disclosed and claimed in my co-pending application which has matured into Patent No. 1,880,092, granted Sept. 27, 1932. A device of this sort is characterized by a relatively large plate current of the order of several amperes which effectively may be controlled by an exceedingly small grid energy of the order of a fraction of a micro-watt. Hence, a tube of this character may operate directly a large current relay in the output circuit without the necessity of further amplification. In order to derive a large current carrying capacity, a cathode of unusual design is employed having considerable surface area to emit electrons profusely at reduced operating temperatures; the grid or control member is also of special form.

Upon the application of suitable alternating voltage to each of the cathode, cathode-grid and cathode plate circuits, a discharge is produced which assumes an arc-like character, i. e., has a negative or substantially zero volt-ampere characteristic, the discharge beginning in each alternating current voltage cycle at a time dependent upon the magnitude of the grid bias and continuing until the end of the cycle. Upon formation of the discharge, the grid loses control and the arc continues for the remainder of the half cycle during which the anode member is positive. However, when the alternating current reverses, the discharge stops abruptly and control is restored to the grid at the time the anode starts to become positive again.

As shown in the drawing, the arc discharge device takes the form of an evacuated envelope 15, containing a cylindrical cathode, an anode 17, and a control member 18, enclosing the cathode. The latter is of multi-cellular design and constructed to provide a plurality of cavities open to the exterior and having a surface which emits electrons profusely at reduced operating temperatures. These cavities conveniently may comprise the space between longitudinally extending metallic vanes 19 arranged equidistantly about and extending between the peripheries of two concentrically mounted cylinders 20 and 21. The cylinders may consist of nickel, or an alloy of tungsten or molybdenum containing thorium oxide.

Within the inner cylinder 20 is a heater 22 in the form of a coil or helix, one end of which is connected by welding, riveting or otherwise, to the thickened end wall 23 of the inner cylinder. The lower end of the heater may be attached by welding or other suitable method, to a rigid leading-in conductor 24. In order to prevent the coil heater from striking against the interior metallic surface of the cylinder 20 and thus cause a short circuit, there is provided a lining 25, consisting of a refractory insulating material such as magnesia, alumina or thoria, snugly fitted within the cylinder. The cathode, as a whole, may be supported from the reentrant stem 26 by means of two rods 27, affixed to the outer cylinder 21, one of the rods serving as a leading-in conductor for the heater.

The electrostatic control or grid member 18 consists of suitable sheet metal with holes punched therein to a number and size depending upon the amplification characteristic desired, and formed as a cap which sets over the cathode. It is rigidly supported in this position by wires 28, which are attached to a clamp 29 securely mounted on the stem 26. The location of the grid surrounding the cathode and spaced closely adjacent thereto causes the latter to be entirely shielded by the grid from the electrostatic influence of the walls of the envelope. The anode 17 is simply a metallic plate of rugged character supported by a conductor which passes through the upper portion of the envelope.

The lower end of the envelope is somewhat enlarged and has coated directly on its surface, preferably the interior, in any suitable manner, two physically-separate juxtaposed films 30 of material whose resistance changes in accordance with light variations, for example, selenium. These films are of equal surface area and each electrically connected to the clamp 29 and hence, to the control member 18, by conductors 31. Suitable leading-in wires extend from the selenium surface to the exterior of the envelope where, if desired, they may be connected to contact plugs (not shown). The combined amplifier and light sensitive apparatus may be completed by a thorough evacuation of the envelope while heating to a baking temperature to denude the glass and the metal parts, of the gas held in occlusion and admitting a quantity of inert gas, for example, argon, at a pressure of the order of about 5-20 microns or a drop of mercury to evolve vapor sufficient for the initiation of a large current-carrying discharge under operating conditions.

The device is energized from an alternating current source, preferably of commercial voltage and frequency, the grid and heater circuits being supplied through a transformer secondary 32, the primary 33 of which is connected to the

alternating current source. The plate or output circuit is directly across the full line voltage. The output circuit includes a direct current relay 34 of substantial size adapted to actuate contacts which may control any form of mechanism or circuits which it is desired to operate in response to changes of a light source 35, for example a valve in an oil pipe line or coal chute leading to a furnace (not shown).

It is apparent that when the various circuits are energized and the selenium films are both in the dark, the grid member 18 derives equal positive and negative charges from the transformer, one of the charging currents flowing through one of the films and the other passing through the opposite film in the same manner as is explained with reference to Fig. 2. The resistance of each film is so large as to prevent an appreciable amount of current flowing to the control member, in fact, there is only sufficient current to effectively charge this member. Under these conditions, it is evident that the average potential of the grid with respect to the average potential of the cathode cylinder 21 is determined by the number of turns between the center point of the secondary 32 and the end of the transformer attached to said cylinder. When the instantaneous voltages of the system are such that the anode 17 becomes positive and the number of turns of winding 32 gives a higher voltage than that of the line, the grid assumes a negative charge and its electrostatic field effectively prevents a discharge between the anode and cathode members. When the control electrode becomes positive on reversal of current, the anode is negative and hence no current can flow for well understood reasons. Accordingly, the charge on the grid is effective in preventing discharge through the device.

However, when one of the films, for example, the one on the right as seen in the figure, is activated by the light source 35, indicated generically as an incandescent lamp but which may constitute the glow from a self-firing furnace and the other remains in a darkened or inactivated state, the resistance of the activated film decreases, with the result that a greater charging current flows through this film than through the other and the equilibrium potential of the grid with respect to the cathode undergoes a change. The grid now assumes a potential corresponding to a position in the secondary intermediate the center tap and the right hand terminal, i. e. the magnitude of the grid potential approaches that of the cathode. The average value of the alternating current bias accorded the grid is a measure of the unbalanced selenium film resistances, which is also a measure of the intensity of light impinging on the activated film.

While the position of the filament taps has been shown at the extreme right-hand end of winding 32, it is obvious that they may be adjusted to accord a proper potential balance to the grid or rather to apply on the grid a charge of suitable polarity and magnitude in order that the system may become highly sensitized. It is also apparent that this adjustment should be such that when the films 30 are both activated, there is substantially no current flow through the relay 34. As in the case of Fig. 2, the condition of no current through relay 34 may be consonant with the condition of balance in the bridge circuit. The position of the filament taps should be such that when the reference light changes the resistance of one of the films, the charge on the grid may cause an arc discharge to take place between the cathode and anode members. As a result of the discharge, a relatively large rectified current flows through the output circuit to energize the relay 34.

It will be evident to those skilled in the art that the position of the selenium within the envelope is considered preferable to the exterior coating on a block of insulation shown in Fig. 2 for the reason that the envelope and the enclosed vacuum afford considerable mechanical and moisture protection respectively to the films. The construction in Fig. 3 represents the invention in simplified form and constitutes a compact, rugged and dependable unit. While the position of the selenium film or layers on the interior surface of the envelope represents a very simple construction, it is evident that, if desired, the light-sensitive material may be coated on an insulating, heat conducting member, for example, glass, mounted within the envelope in any suitable manner.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. Light-sensitive apparatus comprising an envelope containing a plurality of cooperating electrodes, a light-sensitive resistance coating on the envelope and electrically connected to one of said electrodes.

2. Light-sensitive apparatus comprising an envelope containing a plurality of cooperating electrodes including an electrostatic control member, a light-sensitive resistance coating on the envelope and electrically connected to said control member.

3. An envelope containing a plurality of electrodes immersed in a gas having a pressure of the order of about ten microns, and a plurality of separated light-sensitive layers affixed to the envelope and electrically connected to one of said electrodes.

4. Light-sensitive apparatus comprising an envelope containing a plurality of cooperating electrodes including an electrostatic control member, a plurality of separated light-sensitive layers affixed to the envelope and electrically connected to said control member.

5. Light-sensitive apparatus comprising an envelope containing an ionizable medium at a pressure sufficient to support an arc-like discharge at the impressed voltages, said envelope also including a plurality of cooperating electrodes including an electrostatic control member, a plurality of separated selenium layers affixed to the envelope and electrically connected to said control member.

ALBERT W. HULL.