Dec. 18, 1934. A. A. THOMAS 1,984,777

PHOTO ELECTRIC CELL

Filed April 4, 1931

FIG. 7.

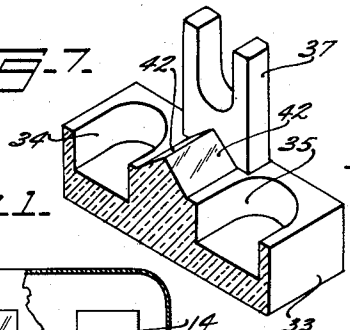



FIG. 1.

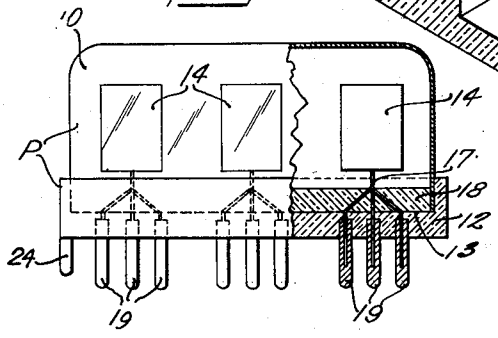



FIG. 2.

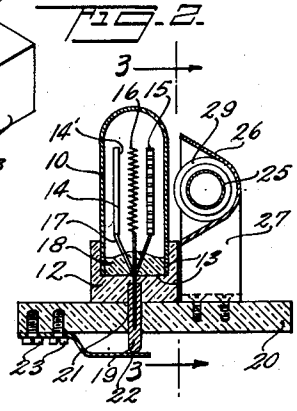



FIG. 3.

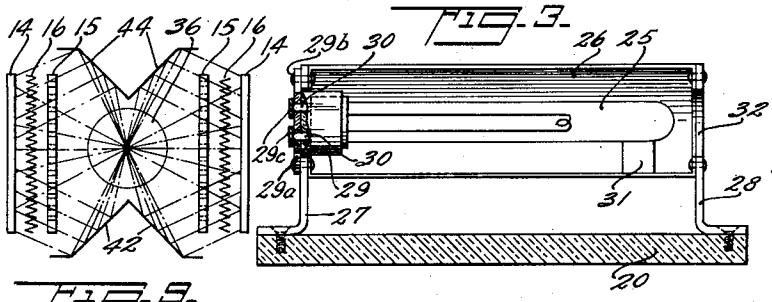



FIG. 8.

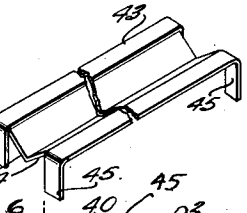
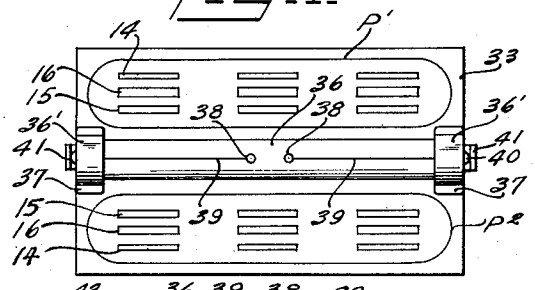



FIG. 9.

FIG. 4.



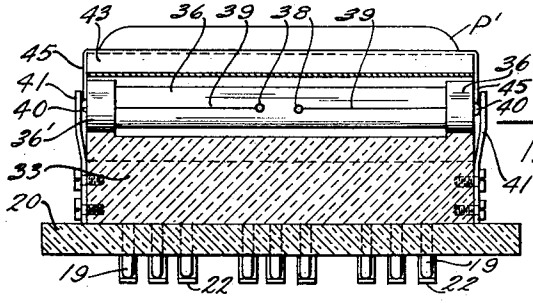




FIG. 6.

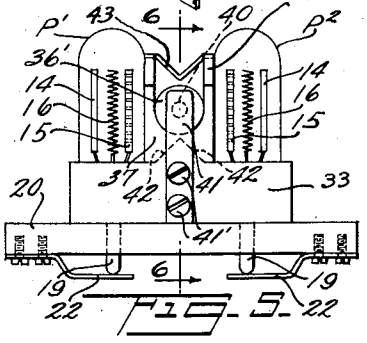



FIG. 5.

INVENTOR

Adolph A. Thomas

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## PHOTO-ELECTRIC CELL

Adolph A. Thomas, New York, N. Y.

Application April 4, 1931, Serial No. 527,671

13 Claims. (Cl. 250—41.5)

This invention is for photo-electric cells of novel construction adapted to produce multi-stage amplification of electric impulses. One feature of my invention comprises a cell or tube having a straight flat envelope in which several sets of electrodes are mounted in a straight path. Each set of electrodes consists of an anode, a grid and a photo-electric cathode, and a single electric lamp is arranged to illuminate all cathodes simultaneously with the same intensity. For this purpose I use a lamp having a long bulb which is mounted in close parallel relation to the photo-electric cell, and a suitable reflector concentrates the light rays on the cathodes. The anodes are perforated or otherwise constructed to permit the passage of light. Each set of electrodes represents a stage of radio or audio amplification. In a more elaborate form of my invention, I mount two multi-stage photo-electric cells on opposite sides of an elongated electric lamp, and these elements may be mounted on a common base to constitute a unitary device.

The novel features and practical advantages of my invention will be understood from a description of the accompanying drawing, in which—

Fig. 1 is a rear face view of my new photo-electric cell, partly sectioned for clearness;

Fig. 2 is a transverse section of the photo-electric cell mounted in operative relation to an electric lamp;

Fig. 3 represents a longitudinal section on line 3—3 of Fig. 2 to show the support of the lamp;

Fig. 4 is a plan view of two photo-electric cells and an electric lamp mounted on a common base, the top reflector for the lamp being omitted;

Fig. 5 is an end view of the assembly shown in Fig. 4, with the top reflector for the lamp in position;

Fig. 6 is a longitudinal section on line 6—6 of Fig. 5;

Fig. 7 is a perspective of a portion of the insulating base on which the photo-electric cells and lamp of Figs. 4–6 are mounted;

Fig. 8 is a perspective of the top reflector for the electric lamp of Figs. 4–6; and

Fig. 9 is a diagram indicating how the reflectors in Figs. 4–6 concentrate the light rays on the cathodes of the photo-electric cells.

Referring to Figs. 1 and 2, the photo-electric cell P comprises a flat elongated envelope 10 mounted on an insulating base 12, which is preferably molded of unbreakable material. The base 12 has a rectangular recess 13 for receiving the lower end of envelope 10, which is sealed to the base. The vacuum chamber of photo-electric cell P contains several sets of electrodes, there being three sets shown in Fig. 1 by way of example. Each set of electrodes consists of a light-sensitive cathode 14, an anode 15 and an interposed grid 16. These electrodes are rigidly supported in any practical way, as by being mounted on metal stems 17, which are embedded in the glass base 18 at the bottom of envelope 10. The conducting stems or rods 17 are connected to contact pins 19 projecting from the insulating base 12. It will be understood that one contact pin of each set is electrically connected to one of the electrodes, and it is convenient to arrange all the contact pins in a straight line centrally of the base. Any suitable support may be used for holding the photo-electric cell P in operative position. In Fig. 2 there is an insulating plate 20 provided with holes 21 through which the contact pins 19 project into engagement with conducting members 22. These members may be in the form of resilient fingers or blades of brass attached at one end by screws 23 to the underside of plate 20, and one of the screws may be used as a binding post for a conductor. To compel the correct positioning of the photo-electric cell on plate 20, the base 12 may be provided at one end with a dummy plug or pin 24, which fits into an opening in the plate when the cell is in proper position.

The cathode 14 of each set of electrodes is coated on the front side 14′ with a substance adapted to emit a flow of electrons under the action of light rays. The electronic surface 14′ may be mounted on a plate of conducting metal, such as nickel, and it may also be applied directly to the adjacent surface of the transparent envelope 10. Various materials may be used for the electronic cathode surface 14′, such as alkaline metals or compounds, particularly sodium, potassium, rubidium and caesium. A potassium cell is most sensitive to blue and green rays, while a caesium oxide cell responds most efficiently to the red end of the spectrum. Cathodes of lithium or cadmium have been found to give maximum electron emission in ultra-violet light. In the last-named instance the envelope 10 should obviously be transparent to ultra-violet rays. Fused quartz is suitable for that purpose, and recently certain kinds of borated glass have been found to be

freely pervious to the ultra-violet end of the spectrum. The electrodes 15 and 16 are constructed of wire or otherwise apertured to permit the passage of light to cathodes 14. When the latter require ultra-violet rays for most efficient operation, the anodes 15 may be thin plates of quartz coated on the inner side with a thin film of silver, which is transparent to ultra-violet light and yet presents a solid conducting surface to the electrons from the associated cathodes 14.

Each set of electrodes 14, 15 and 16 represents a stage of amplification and the successive stages are connected in any practical way, as heretofore used in radio receiving systems. It will not be necessary to show or describe any circuits for the sets of electrodes 14, 15 and 16, because the amplifying system in which the photo-electric cell is used does not, of itself, form part of my present invention. I need only point out that, in the operation of the multi-stage photo-electric cell P, the cathodes 14 are illuminated simultaneously with substantially the same degree of intensity, and for this purpose I mount an electric lamp 25 as close to the cell as possible. As shown in Fig. 3, the lamp 25 is of elongated form, so as to flood the sensitized surfaces of all cathodes 14 with light of uniform intensity. The lamp 25 may be of the filament type, or it may be a glow tube capable of emitting the proper kind of light, depending upon the character of the electronic surfaces 14'. For example, a neon tube gives red light, and an argon tube emits chiefly blue and green rays.

The activating lamp 25 is mounted in close parallel relation to photo-electric cell P in any practical way. In Figs. 2 and 3, the lamp support comprises a trough-shaped or parabolic reflector 26 supported by a pair of end brackets 27 and 28, which are fixed on the insulating plate 20. The bracket 27 carries an insulated socket 29 provided with a flange 29*a* which is secured to the bracket by screws or rivets 29*b*. The flange 29*a* carries a pair of contacts 29*c* arranged to engage the terminal pins 30 of lamp 25 when the latter is inserted in socket 29. The free end of lamp 25 may rest on a cushioning block or pad 31 attached to the trough 26 in any practical way. The bracket 28 may have an opening or cut-out portion 32 to facilitate insertion and removal of lamp 25. The inner surface of member 26 is silvered or highly polished to reflect the light of lamp 25 toward the cathodes 14. The close mounting of lamp 25 to the photo-electric cell increases the electronic emission of cathodes 14. The photo-electric cell may be inserted on and removed from plate 20 without disturbing the lamp 25 in its support.

In the modification illustrated in Figs. 4–9, there are two photo-electric cells $P^1$ and $P^2$ mounted on a common insulating base 33, which is preferably molded of composition material like phenol condensation products. The base 33 is formed with two parallel recesses 34 and 35 shaped to receive the flat elongated envelopes of the cells, as previously explained in connection with Figs. 1 and 2. Each photo-electric cell $P^1$ and $P^2$ has several sets of amplifying electrodes 14, 15 and 16, which are like the electrodes above described for the single cell P. The base 33 is provided with two rows of contact pins 19, to which the electrodes 14, 15 and 16 are electrically connected, as previously explained. The photo-electric cells $P^1$ and $P^2$ are illuminated simultaneously by an electric lamp 36 arranged between the cells and parallel therewith. It is convenient to mount the lamp 36 on base 33, and for that purpose I provide the base with integral extensions 37, which are recessed to receive the cylindrical end portions 36' of lamp 36. In other words, the extensions 37 are like a pair of cradles for receiving the ends of lamp 36 in a snug fit. In the present instance the lamp 36 is of the glow type, having a pair of spaced electrodes 38 which are connected by rods or stiff wires 39 to contacts 40 projecting from the ends of the lamp. The base 33 carries a pair of spring contact arms 41 secured by screws 41' and adapted to engage the contacts 40 of lamp 36 when the latter is inserted in the cradles 37. One of the screws 41' of each contact arm may be used as a binding post for a conductor. The spring arms 41 also serve to hold the lamp 36 firmly in place.

The insulating base 33 of the double photo-electric cell $P^1$—$P^2$ is provided with an integral V-shaped ridge having surfaces 42 adapted to reflect light in opposite directions against the cathodes 14 of the cells. I may also use an upper reflector 43 provided with V-shaped reflecting surfaces 44 adapted to direct light rays against the cathodes. The diagrammatic view in Fig. 9 illustrates the action of the oppositely arranged reflecting surfaces 42 and 44 in concentrating practically all the light of lamp 36 on the cathodes 14 of cells $P^1$ and $P^2$, so that all the cathodes are simultaneously illuminated with uniform maximum intensity. The upper reflector 43 is removably mounted on the cradles 37 in any practical way, as by means of prongs 45 adapted to engage the upper ends of cradles 37 in a tight frictional fit. Instead of the reflectors 42 and 43, I may use a pair of cylindrical lenses between lamp 36 and photo-electric cells $P^1$ and $P^2$ for concentrating the light rays on cathodes 14, but I think the reflectors are cheaper to make and work just as well. The spaced cells $P^1$—$P^2$ and the interposed lamp 36 can also be made as three separate members, each mechanically independent of the other, but the construction above described presents a unitary device adapted to be mounted on and removed from the supporting plate 20 as a single piece.

One of the photo-electric cells $P^1$—$P^2$ may be used for radio amplification and the other for audio amplification, and each cell contains as many sets of electrodes as there are stages of amplification. The close parallel arrangement of lamp 36 to cells $P^1$—$P^2$ gives a multi-stage amplifying unit of high efficiency, since almost the entire light output of the lamp is concentrated on the cathodes 14. It is not always necessary that the photo-electric cells $P^1$—P shall be identical in structure, for in some cases it may be desirable to construct the cells differently. For example, one of the cells may have a high vacuum and the other may be filled with an inert gas at low pressure. This also applies to cell P of Figs. 1–2. The flat structure of my new photo-electric cell gives a small compact unit capable of producing several stages of amplification, so that only one of the double-cell units is necessary for a radio receiver capable of operating a loudspeaker. It will be understood that my new photo-electric cell is not limited to radio receivers, but is applicable in any electric system employing multi-stage electronic amplification. It is hardly necessary to add that the drawing does not show the various

parts in exact proportions, for I have purposely exaggerated some parts (especially the electrodes) for clearness. It will therefore be understood that the figures are not shop drawings made to manufacturing scale.

Although I have shown and described certain specific constructions, my invention is not limited to the details set forth, for it is possible to make changes and alterations without departing from the scope of the invention as defined in the appended claims. When I describe the envelopes for the photo-electric cells as being flat, I mean that they have a shape which differs from cylindrical by having a pair of opposite sides with substantially flat surfaces arranged close together, like the top and bottom of a shallow box.

I claim as my invention:

1. The combination of a photo-electric cell having an elongated flat envelope in which a plurality of sets of electrodes are mounted in spaced alignment in the direction of the flatness of said envelope, each set of electrodes including an anode, a control element and a light-sensitive cathode, and an elongated electric light bulb separate from said cell and mounted in close parallel relation to said cell for simultaneously illuminating all of said cathodes.

2. The combination of a base, a photo-electric cell operatively mounted on said base, said cell having an elongated flat envelope containing a plurality of sets of electrodes mounted in spaced alignment in the direction of the flatness of said envelope, each set of electrodes including an anode, a control element and a light-sensitive cathode, a support fixed on said base adjacent said cell, and an elongated electric light bulb separate from said cell and mounted on said support in close parallel relation to said cell for simultaneously illuminating all of said cathodes.

3. The combination of a photo-electric cell having an elongated flat envelope containing a plurality of sets of electrodes mounted in spaced alignment in the direction of the flatness of said envelope, each set of electrodes including a light-sensitive cathode, a support fixed adjacent said cell, an elongated electric light bulb separate from said cell and mounted on said support in close parallel relation to said cell for simultaneously illuminating all of said cathodes, and reflecting means on said support for concentrating the light on said cathodes.

4. The combination of a base, a photo-electric cell operatively mounted on said base, said cell having a straight flat envelope containing a plurality of sets of electrodes mounted in spaced alignment in the direction of the flatness of said envelope, each set of electrodes including an anode, a control element and a light-sensitive cathode, a support fixed on said base adjacent said cell, an elongated electric light bulb separate from from said cell and mounted on said support in close parallel relation to said cell for simultaneously illuminating all of said cathodes, and reflecting means on said support for concentrating the light on said cathodes.

5. The combination of a base, a photo-electric cell operatively mounted on said base, said cell having a straight flat envelope containing a plurality of sets of electrodes, each set of electrodes including a light-sensitive cathode, a trough-shaped support fixed on said base adjacent said cell and open toward the cell, and an elongated electric light bulb mounted on said support in close parallel relation to said cell for simultaneously illuminating all of said cathodes, the inner surface of said trough-shaped surface being adapted to reflect light rays toward said cathodes.

6. The combination of a base, a photo-electric cell operatively mounted on said base, said cell having a straight flat envelope containing a plurality of sets of electrodes, each set of electrodes including a light-sensitive cathode, a trough-shaped support fixed on said base adjacent said cell and open toward said cell, a lamp socket at one end of said support, and an elongated electric light bulb having contacts at one end removably mounted in said socket, and means in said support for engaging the free end of said bulb, which is thereby firmly supported in close parallel relation to said cell for simultaneously illuminating all of said cathodes.

7. The combination of a pair of photo-electric cells having each a straight flat envelope containing a plurality of sets of electrodes, each set of electrodes including a light-sensitive cathode, means for supporting said cells in spaced parallel relation, and an elongated electric light bulb supported between said cells and parallel thereto for simultaneously illuminating all the cathodes of both cells, said elongated bulb being mounted with its axis in the direction of the flatness of said cells.

8. The combination of a pair of photo-electric cells having each a straight flat envelope containing a plurality of sets of electrodes, each set of electrodes including a light-sensitive cathode, means for supporting said cells in spaced parallel relation, and an elongated electric glow lamp supported between said cells for simultaneously illuminating the cathodes of both cells with substantially equal intensity, said elongated glow lamp being mounted with its axis in the direction of the flatness of said cells.

9. A unitary photo-electric cell assembly comprising an insulating base, a pair of straight flat envelopes mounted on said base in spaced parallel relation, a plurality of sets of electrodes mounted in each envelope, each set of electrodes including a light-sensitive cathode, contact pins electrically connected to said electrodes and projecting from said base, and means for supporting an electric lamp between said cells for simultaneously illuminating all of said cathodes, said electric lamp having a long straight bulb fitting lengthwise between said flat envelopes in close parallel relation therewith.

10. The combination of a pair of photo-electric cells having each a straight flat envelope containing a plurality of sets of electrodes, each set of electrodes including a light-sensitive cathode, means for supporting said cells in spaced parallel relation, an elongated electric light bulb supported between said cells and parallel thereto for simultaneously illuminating the cathodes of both cells, and reflecting means associated with said bulb for directing light rays to all cathodes on both sides of the bulb.

11. The combination of a pair of photo-electric cells having each a straight flat envelope containing a plurality of sets of electrodes, each set of electrodes including a light-sensitive cathode, means for supporting said cells in spaced parallel relation, an insulated support arranged between said cells, a pair of contact members at opposite ends of said support, and an elongated electric lamp mounted on said support with its axis in the direction of the flatness of said envelopes and having contacts at its ends arranged

to engage said contact members, said lamp being adapted to illuminate the cathodes of both cells at the same time.

12. The combination of a pair of photo-electric cells having each a straight flat envelope containing a plurality of sets of electrodes, each set of electrodes including a light-sensitive cathode, means for supporting said cells in spaced parallel relation, an insulated support arranged between said cells, a pair of contact members at opposite ends of said support, an electric lamp mounted on said support and having contacts at its ends arranged to engage said contact members, said lamp being adapted to illuminate the cathodes of both cells at the same time, and reflectors arranged above and below said lamp for directing light rays to all cathodes on both sides of the lamp.

13. A unitary photo-electric cell assembly comprising an insulating base, a pair of straight flat envelopes mounted on said base in spaced parallel relation, a plurality of sets of electrodes mounted in each envelope, each set of electrodes including a light-sensitive cathode, contact pins electrically connected to said electrodes and projecting from said base, means integral with said base for supporting an electric lamp between said cells for simultaneously illuminating all of said cathodes, and reflectors arranged above and below said lamp for directing light rays to all cathodes on both sides of the lamp, the upper reflector being removable to permit access to the lamp.

ADOLPH A. THOMAS.