

Aug. 22, 1944.

J. R. BALSLEY
LIGHT CONTROL MEANS

2,356,195

Filed May 23, 1941

2 Sheets-Sheet 1

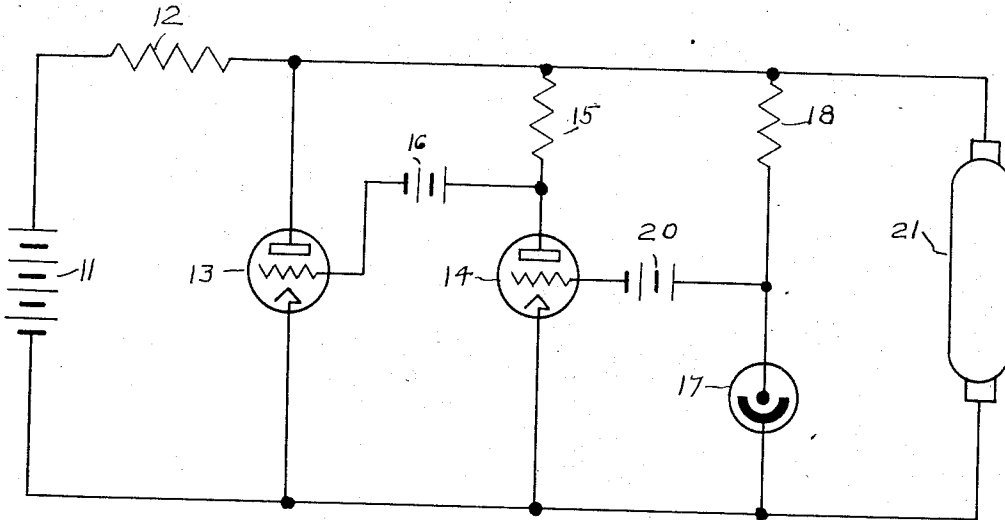


Fig. 1

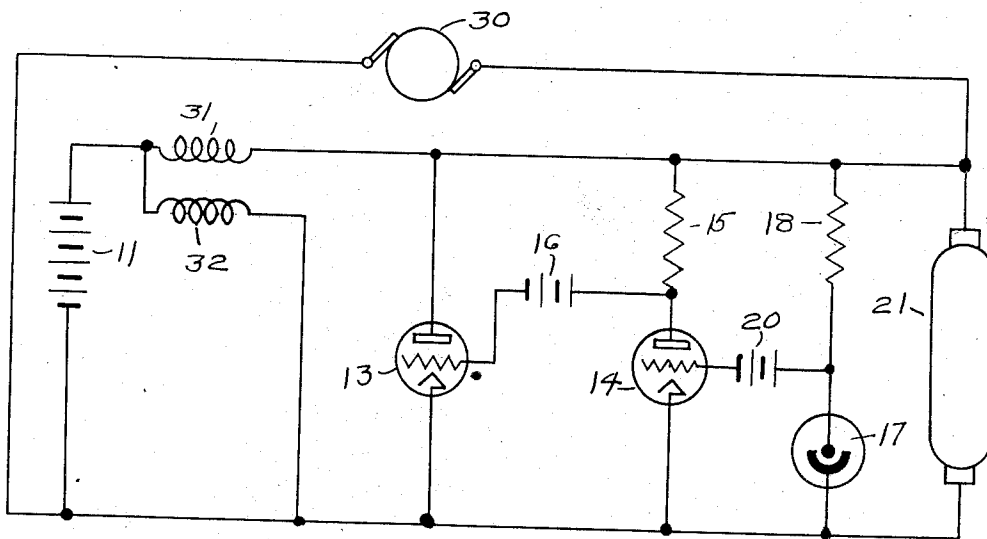


Fig. 2

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2 Sheets-Sheet 2

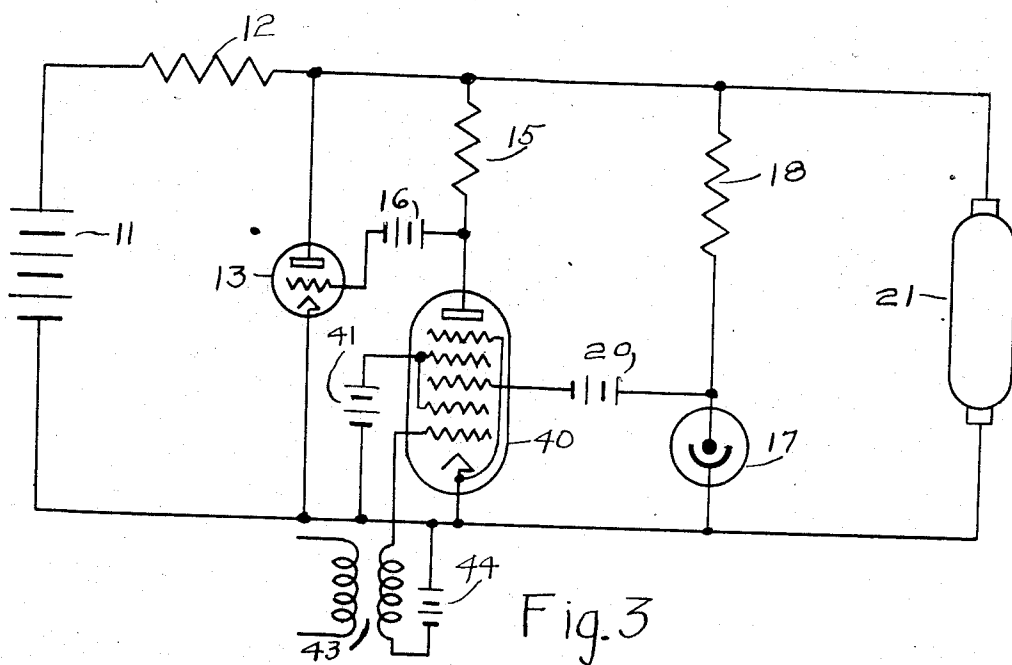


Fig. 3

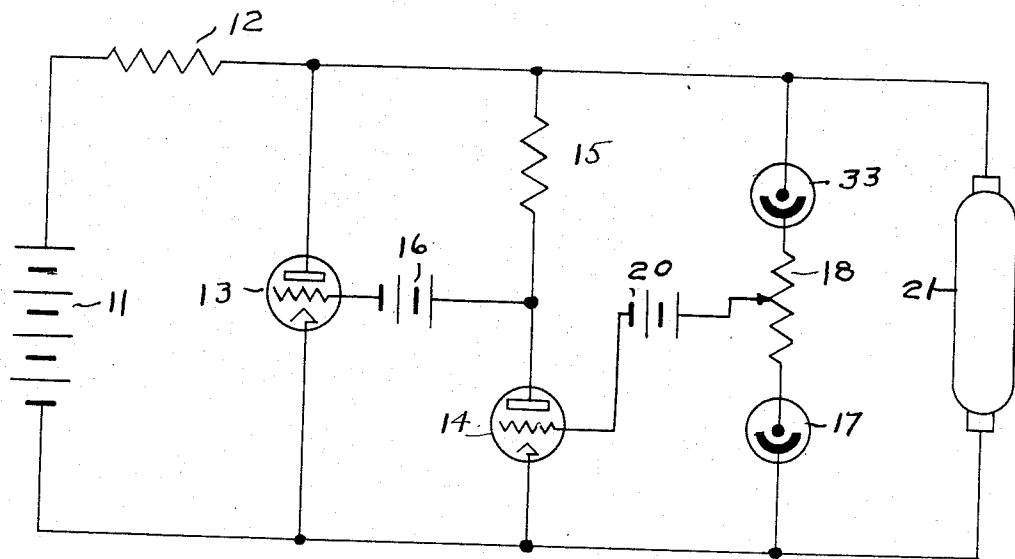


Fig. 4

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UNITED STATES PATENT OFFICE

2,356,195

LIGHT CONTROL MEANS

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Application May 23, 1941, Serial No. 394,903

12 Claims. (Cl. 315—151)

The present invention relates to means for controlling and stabilizing electrically energized light sources, and particularly to means for stabilizing such light sources through the use of what may be termed "optical feedback."

In my prior patent, No. 2,242,638, issued May 20, 1941, I disclose a means for maintaining a constant light intensity utilizing an electron discharge tube in series with a light source, the impedance of said tube being varied by the voltage from a photoelectric cell receiving its excitation from the controlled light source.

The present invention employs the same optical feedback principle as disclosed in the aforesaid patent, but in this instance the controlling electron discharge tube is in shunt with the light source rather than in series with it. The present invention thereafter acts to achieve the same result as the prior one, but does this in a different mode which is in some instances preferable.

It is an object of the invention to provide a means for controlling and stabilizing electrically energized light sources utilizing an electron discharge tube in shunt with the controlled light source.

It is a further object of the invention to provide such a circuit which is simple and economical to install.

Further objects and features of the invention will become clear when the following description is considered in connection with the appended drawings, in which

Figure 1 is a diagram of a circuit for maintaining constant intensity of a light source utilizing an electron discharge tube in shunt with the source;

Figure 2 is a diagram of a circuit similar to Figure 1, in which, however, only a portion of the current to the light source is supplied by an electron discharge tube, the greater portion being supplied by a generator;

Figure 3 is a diagram similar to that of Figure 1, illustrating the modulation of a light source in such a manner that its intensity is varied in accordance with the modulation only without any foreign disturbances; and

Figure 4 is a diagram showing the application of the circuit of Figure 1 to the problem of copying photographs, documents, and the like, making an exact copy as regards density and contrast or giving any desired variation of either or both irrespective of the latent contrast of the copy paper or film being used.

Referring to the drawings and especially to Figure 1, there is shown at 11 a battery or other

current source which supplies power to the lamp and to the control unit. In series with the battery is a voltage dropping resistance 12. Connected between the low potential side of resistance 12 and the negative terminal of current source 11 is an electron discharge tube 13, said electron discharge tube being shown as a triode, that is, a tube having anode, cathode and control electrode.

Likewise connected between the low potential side of resistance 12 and the negative terminal of battery 11, is a second electron discharge tube 14, in series with which is a resistance 15. Tube 14 is also a triode, having an anode, cathode, and grid, the anode of tube 14 being connected through a battery 16 to the grid of tube 13 whereby a negative potential is put on the grid of tube 13.

Also connected from the low potential side of resistance 12 to the negative terminal of battery 11, is a photoelectric cell 17, in series with a resistance 18, said resistance being a coupling resistance. Intermediate the coupling resistance 18 and the photoelectric cell 17 is a connection which leads through a battery 20 to the grid of tube 14.

Lamp 21 which is the light source to be controlled, is likewise connected from the low potential side of resistance 12 to the negative terminal of battery 11, this lamp being arranged so that a portion of the light therefrom reaches the photoelectric cell 17.

Voltage adjustments on tubes 13 and 14 are made such that a portion of the current flowing through resistance 12 flows through lamp 21, while another portion flows through tube 13. Tube 14, being an amplifier tube, takes very little current and therefore the current through this tube may be neglected in analyzing the performance of the circuit.

When the voltages are adjusted as described above, if the intensity of the light from lamp 21 increases for any reason, as for example due to a change in ambient temperature, this will bring about a reduction of the resistance of cell 17, thus causing the grid of tube 14 to become more negative. This, in turn, reduces the voltage drop across resistance 15, causing the grid of tube 13 to become more positive, thus increasing the total current through resistance 12 and, of course, reducing the voltage across lamp 21. In a similar manner, if the light intensity tends to decrease, the resulting decrease in current through resistance 12 will compensate for this tendency.

In the event that a constant current source is

available, it is obvious that resistance 12 may be eliminated, since the photoelectric cell 17 will then control the current flow through tube 13, which is one of the two major paths available for the current, the other being the lamp itself.

For uses where the disturbances which tend to alter the intensity represent depths of modulation which are appreciably less than one hundred per cent, that portion of the current which will be considered as the "steady" current may be supplied by a battery or by a generator. The portion of current required to compensate for disturbances may be regulated by the use of an electron discharge tube as has been previously described. Figure 2 shows a circuit utilizing a generator for the purpose mentioned, and also for performing another function, that of compensating automatically for slow variations in intensity even of great amplitude. The generator is represented in Figure 2 as having an armature 30 and field windings 31 and 32, the field 31 being so connected that as the current through it increases, the output voltage of the generator is reduced. The circuit components 11, 13, 14, 15, 16 and 21 function exactly as described above in connection with Figure 1 for all light variations which occur at frequencies higher than a few per second.

For slow changes they have an additional function that of altering the output of the generator through automatic variations of the field strength. These variations will take place at frequencies up to a limit which is determined by the characteristics of the generator itself.

This type of circuit has practical application for such operations as the printing of motion picture film where it is imperative that the average value of light intensity be kept constant and where rapid variations of intensity of as little as a few per cent may ruin the print. It may also be used to compensate for variations in intensity normal for any carbon arc.

In Figure 3 there is shown a circuit which is generally similar to that of Figure 1, the circuit of Figure 3 being particularly designed, however, to permit of modulation of a light source. Like parts in Figure 3 have been given the same reference characters as in Figure 1 for the purpose of convenience. In connection with Figure 3, it may be stated that this arrangement permits the use of a mercury vapor lamp, which has not heretofore been possible except in a series arrangement as shown in my Reissue Patent No. 21,907. In the past, low pressure gas discharge tubes have been utilized for modulation purposes, as for example for recording sound on film, but these tubes were not satisfactory due to insufficient light intensity and non-linear characteristics. When mercury was added to such lamps or used alone, the intensity was increased to the desired value but other difficulties arose. Used in this manner, non-uniform characteristics were produced which were difficult or impossible to compensate. The response was consequently deficient in high frequencies, distortion was high, and, in addition, the average intensity could not be controlled within sufficiently close limits to meet modern requirements. Incandescent lamps have likewise been utilized for the purposes of recording and other uses involving modulation but were unsatisfactory since the thermal inertia of the filaments was too great for practical usage at high frequencies.

In making photographic sound records it is customary to focus the light source on a narrow

slit and to focus the image of the slit on the film. Unless the light source, lenses, cell, and all other parts of the system are very firmly fixed, vibration occurs which creates a variation in light intensity on the film which is eventually reproduced as so called microphonic noise. The same result obtains if the filament of an incandescent lamp vibrates or the arc in a gas discharge tube does not remain in constant position. All of the above are disadvantages which are extremely difficult to overcome by mechanical means. If a circuit such as that of Figure 3 is utilized and means provided to illuminate the photo-electric cell 17 from a point between the last of the disturbing elements and the film, all disturbances, whether arising from the lamp itself or from any of the elements between the lamp and the film, will be compensated.

In the circuit of Figure 3, current is supplied from the source 11 to the electron discharge tube 13 and the lamp 21 in shunt in the same manner as described in connection with Figure 1. A simple three-element tube 14 of Figure 1 is replaced in the circuit of Figure 3, for the purpose of circuit simplification, by a multi-element tube 40 containing two control grids. The plate of this tube is connected in a circuit in the same manner as the plate of tube 14 of Figure 1. Tube 40 has a screen grid which is connected through a battery 41 to the high potential side of the battery 41 in a conventional manner. One of the control grids is connected through a battery 20 to the photo-electric cell 17 in the same manner as shown in Figure 1. The second control grid of the tube 40 is connected to its cathode through the secondary of a transformer 43 and a biasing battery 44. The primary of transformer 43 is the modulation input circuit.

Examination of this circuit will show that it provides a negative or inverse optical feedback from the lamp 21 to the input. In brief, a fractional part of the output voltage here designated as β is fed back to the input of the amplifier. Black, in Patent No. 2,102,671, has shown that with an amplifier having a gain of μ , when $\mu\beta$ is large as compared with unity, the relation of output voltage to the input voltage is proportional to

$$\frac{1}{-\beta}$$

and is independent of all other factors. In the case illustrated, the light intensity is proportional to

$$\frac{1}{-\beta}$$

since the feedback voltage, that is, the voltage developed across resistance 18, is a function of the light intensity. It, therefore, follows that the light intensity will be proportional to the modulation voltage at all frequencies where the requirements of feedback and gain are met, and that the light intensity will be independent of all other factors, such as supply voltage changes, ageing of the lamp, mercury sputtering, etc.

Figure 3 illustrates only one of the many circuits which may be employed utilizing the advantages of optical feedback for such purposes as sound recording, signalling, and television. It will be obvious that electrical inverse feedback means alone, while effective for correcting defects within the amplifier, are entirely ineffective for corrections external to that amplifier and that the means of Figure 3 corrects not only for de-

fects arising within the amplifier but also for defects arising between the point in the system where the feedback voltage is applied and the point where the useful work is done by the beam of light.

Figure 4 is a diagram of a circuit which may be used for facsimile reproduction. In this circuit, the circuit of Figure 1 is modified by placing a second photo-electric cell therein, this cell being located between one terminal of the lamp 21 and the resistance 18.

In operating this circuit for copying, as for example copying a document which is faded or yellowed and which is to be copied with substantial contrast between black and white, the document to be copied is scanned by well known means by a spot of light which will be reflected from the scanned surface onto the photo-electric cell 33. Light from the tube 31 is used to scan the surface of the light sensitive paper. In the circuit, as shown in Figure 4, cell 17, cell 33 and resistance 18, together determine the grid bias of tube 14 and consequently the light intensity of lamp 21. Light from the lamp 21 is caused to fall on cell 17 in the same manner as has been described with reference to Figure 1. Then by making proper adjustments a copy may be produced which will be in desired contrast, it being obvious that by altering the connections the copy may be either a positive or negative copy of the original. Details of such adjustments are not given here since they are exactly similar to those mentioned in my Reissue Patent No. 21,907.

While I have described various embodiments of my invention, it is obvious that changes may be made in details of the circuits without in any way departing from the spirit of the invention. Therefore I do not wish to be limited in any way by the foregoing description, but on the contrary wish my invention to be limited only by the appended claims.

What is claimed is:

1. The method of controlling light intensity which comprises energizing a light source in shunt with an electron discharge tube, said tube having a fixed grid bias, causing a portion of the light from said light source to fall upon a photoelectric cell and causing all components of the output of said photoelectric cell to control the plate current of said tube.

2. The method of controlling light intensity which comprises energizing a light source in shunt with an electron discharge tube, said tube having an anode, a cathode and a control grid, causing a portion of the light from said light source to fall upon a photoelectric cell, causing all components of the output of said cell to be impressed upon the input of an amplifier, said amplifier being in series with a source of fixed voltage, and utilizing the output of said amplifier to control the grid voltage of said electron discharge tube.

3. The method of controlling light intensity which comprises energizing a light source in shunt with an electron discharge tube, permitting a portion of the light from said light source to fall upon a photoelectric cell, causing all components of the output of said photoelectric cell to regulate the current flowing through an amplifier tube having a fixed grid bias, and permitting the changed current flow through said amplifier tube to effect a change in voltage on the grid of the electron discharge tube to thereby control the energization of the light source.

4. The method of modulating a light source

and simultaneously controlling the average intensity thereof, which comprises energizing the light source in shunt with an amplifier, providing the amplifier with excess gain over that required, converting a portion of the light to voltage by photoelectric means, and feeding back all components of said voltage to the input of the amplifier with such polarity of direct current components and such phase of alternating current components that the amplifier gain is reduced to the required value for all components.

5. In a system for controlling the average intensity and modulation of a light source, an amplifier having an input section and an output section, means for supplying a fixed bias and a modulation voltage to the input section of said amplifier, a lamp connected in shunt with the output section of said amplifier, photoelectric means for converting a portion of the light emitted by said lamp to voltage, and means for applying said voltage to said input section whereby the gain of the amplifier is reduced.

6. In a light modulating system, the combination of an electron discharge tube having an anode, a cathode and a control grid, a light source connected in shunt with the output circuit of said electron discharge tube, a photoelectric cell in position to receive light from said light source, a second electron discharge tube comprising an anode, a cathode, and a control grid, means to maintain a constant voltage at the cathode of said second electron discharge tube, means to impress all components of the voltage generated in said photoelectric cell on the grid of said second electron discharge tube, means to impress modulation voltage on the grid of said second electron discharge tube, and means in the plate circuit of said second electron discharge tube and connected to the control electrode of said first electron discharge tube to cause the changes in voltage on the control electrode of the second tube to be effective to cause corresponding changes on the grid of said first tube.

7. In a device for controlling light intensity, in combination, a light source, an electron discharge tube connected in parallel with said light source and taking energy therefrom, said tube having a fixed grid bias, and a photoelectric cell mounted in position whereby light from said source falls on said cell, all components of the output current from said cell being effective to alter the voltage on the control electrode of said tube.

8. In a device for controlling light intensity, the combination of an electron discharge tube having an anode, a cathode and a control grid, a light source connected in a parallel circuit with said electron discharge tube, a photoelectric cell in position to receive light from said light source, a second electron discharge tube having a fixed bias on the grid thereof, means to apply the voltage generated in said photoelectric cell to the grid of said second tube, and means comprising an impedance in the plate circuit of said second tube and connected to the control electrode of said first tube whereby the change in voltage on the grid of said second tube is effective to cause a corresponding change in the opposite direction on the grid of said first tube.

9. In a device for controlling light intensity, an electron discharge tube, a generator, a light source and said electron discharge tube in parallel circuit energized by said generator, a connection from a field winding of said generator to said tube, a photoelectric cell positioned to re-

ceive light from said light source, and means controlled by said photoelectric cell for controlling the plate current of said tube, said means being effective to modify the output of said generator in accordance with the variation of plate current in said tube.

10. In a device for controlling the intensity of a light source, the combination of an electron discharge tube having an anode, cathode and control grid, a light source connected in parallel to said electron discharge tube, a photoelectric cell in position to receive light from said source, a second electron discharge tube comprising a cathode, anode and a plurality of control electrodes, means to apply the voltage generated in said photoelectric cell to one of the control electrodes of said second tube, said one of said control electrodes having a fixed bias, means to apply modulation voltages to a second control electrode of said second electron discharge tube, and means in the plate circuit of said second electron discharge tube and connected to the control electrode of said first tube whereby the change in voltage on the control electrodes of the second tube are effective to cause corresponding changes on the grid of said second tube.

11. In a device for copying and facsimile reproduction, in combination, an amplifier, a current source, a light source in shunt with said amplifier, both being energized from said current source, a light sensitive cell positioned to receive light from said light source, a second light sensitive cell adapted to receive light from a document to be copied, and means under the joint control of said first and second light sensitive cells for controlling the gain of said amplifier.

12. In a device for copying and facsimile reproduction, in combination, an amplifier, a current source, a light source in parallel with said amplifier, both being energized from said current source, a light sensitive cell positioned to receive light from said light source, a second light sensitive cell adapted to receive light from a document to be copied, means under the joint control of said first and second light sensitive cells for controlling the gain of said amplifier, and means to adjust the joint control means to vary the control of the amplifier gain.

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