

Feb. 18, 1941.

P. W. DORST

2,232,373

INTEGRATING LIGHT METER APPARATUS

Filed Aug. 8, 1938

2 Sheets-Sheet 1

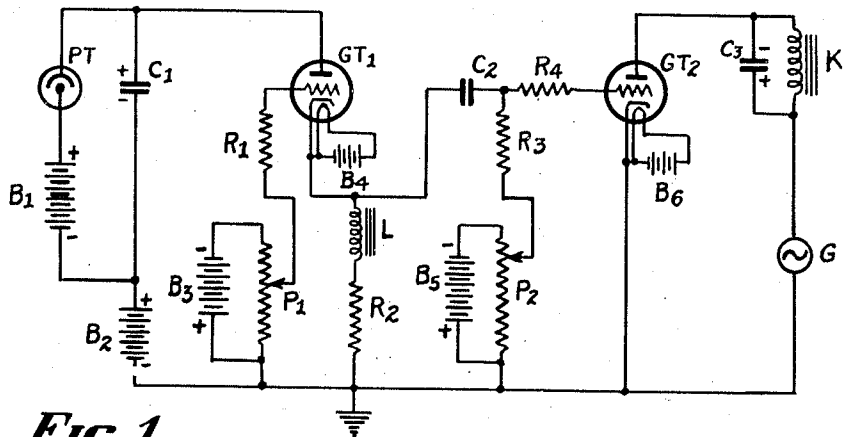


FIG. 1.

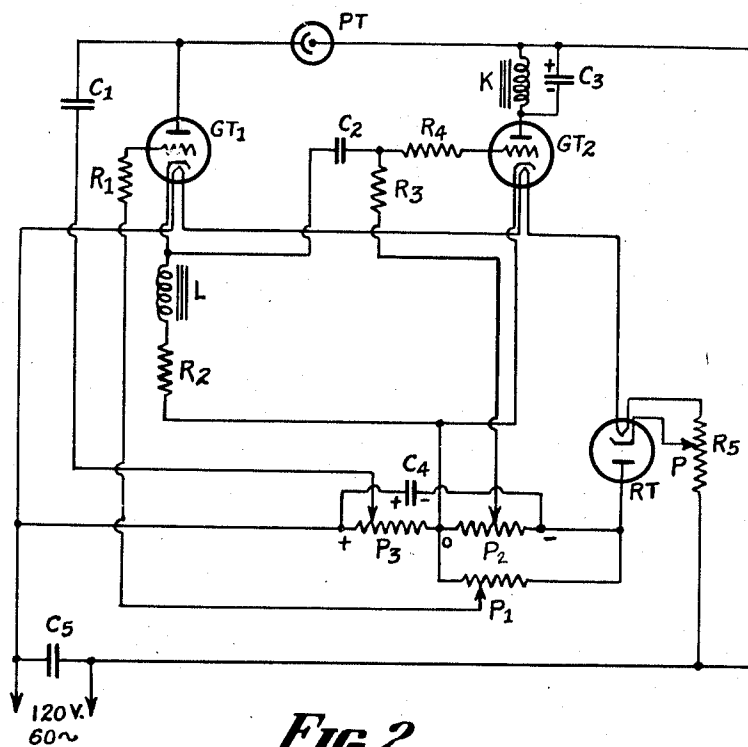


FIG. 2.

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2 Sheets-Sheet 2

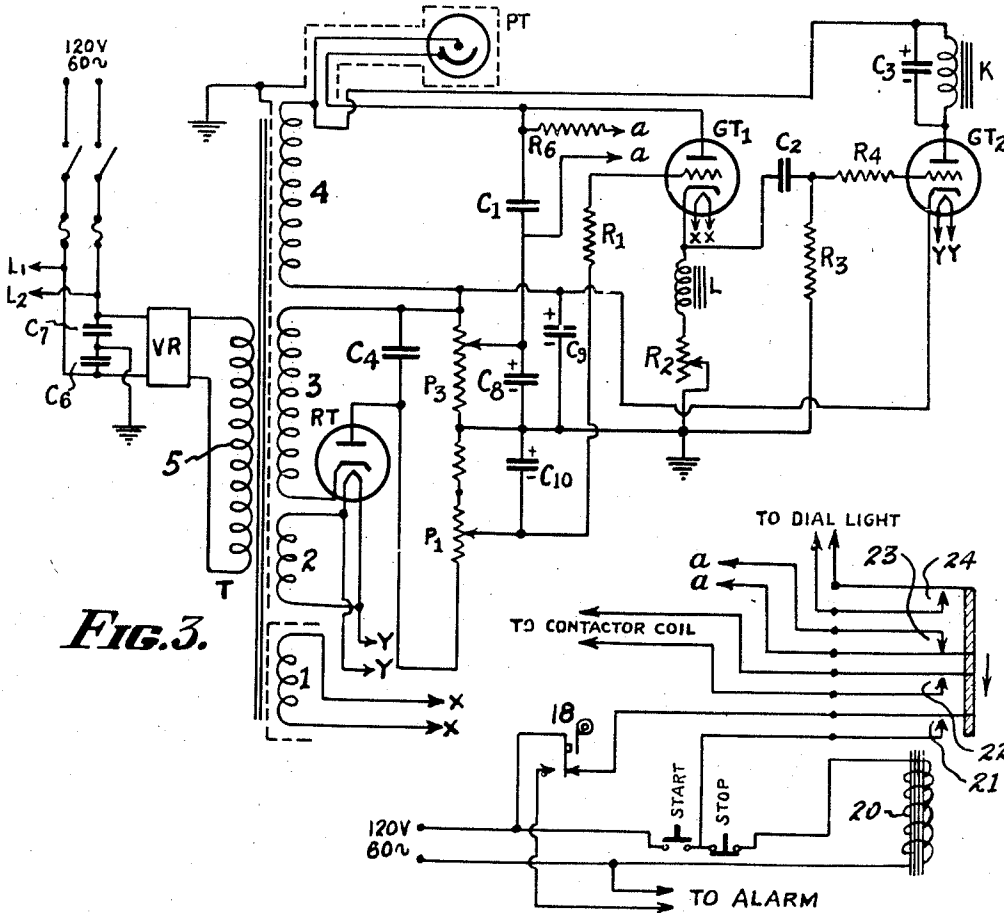


FIG. 3.

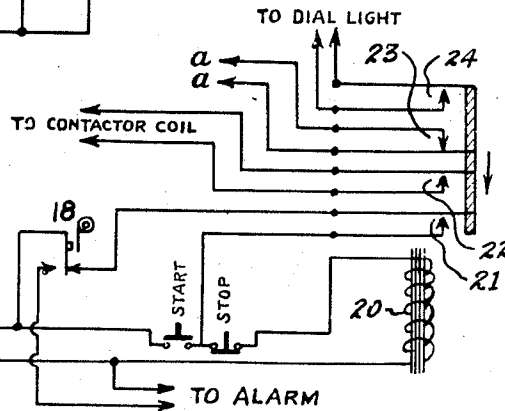


FIG. 5.

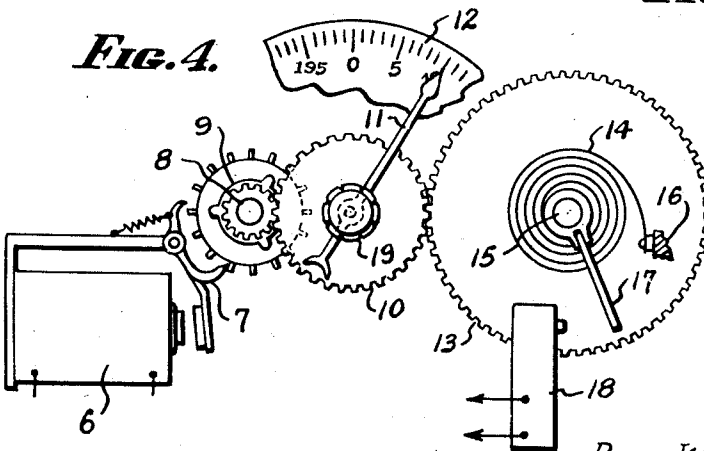


FIG. 4.

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2,232,373

INTEGRATING LIGHT METER APPARATUS

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Application August 8, 1938, Serial No. 223,709

11 Claims. (Cl. 88—23)

This invention relates to the integration of radiant energy involved in photochemical reactions where the intensity of the radiation varies, and where the extent of the photochemical effect is a function of the product of intensity and time.

In the making of photographic reproductions there are three primary factors to be taken into account in securing correct exposure, namely: the sensitivity of the light-sensitive material which is being exposed, the intensity of the light, and the duration of the exposure. In the graphic arts, including photolithography, long exposures are the rule, and variable light sources are usually employed. Thus the need of an integrating light meter will be apparent.

By way of example, in photolithography arc lamps are usually used as a source of illumination in copying. Arc lamps are highly desirable because of their relatively great light intensity; but this intensity cannot easily be kept constant. Beside the fact that highly responsive electrical and mechanical equipment would be necessary if such control were attempted, whereas such equipment is not in common use and is exceedingly expensive, there is the fact that uncontrollable and sporadic variations in the light from the lamps falling on any given surface occur from such factors as line voltage fluctuations, the shapes of the carbon tips as they burn, the position of the flame as it rises from the arc, the swinging of the flame around the carbons and the non-uniformity of the carbons. The result of these variations is to vary the degree of photochemical effect on the sensitized material which is obtained in any given time. The exposure is long enough to permit these sporadic variations to exert an important effect upon the exposure, but not long enough to permit these variations to average themselves out. In many instances the latitude of the sensitized material is not enough to compensate for these variations, and in all work where precise reproduction is desired, there is a clear need for some means of integrating character which will give an exact indication of the total quantity of light falling on a surface in a given time, taking into account the interim variations in intensity. Putting it another way, there is need in the graphic arts of a mechanism which will indicate in point of time when a predetermined quantity of light has fallen on a given surface, no matter how long this takes due to variations in the source.

In the graphic arts also, there is need of an apparatus which can be set for a desired in-

tensity-duration value and which will automatically give an exposure of this value, although the time of such exposure varies with variations in average intensity.

It will be understood that my invention is not only applicable to the exposure of negative material in a camera, but also to the positive printing operation known as plate making, and other operations in the graphic arts; and is also applicable to the control of photo-chemical reactions in general.

It is an object of my invention to provide a device satisfactory to the ends described above.

It is my object to provide a device which will automatically control the exposure of sensitized materials in accordance with the total quantity of light falling thereon. It is my object to furnish an apparatus of this type which is simple in construction and low in cost so that it can be made available to the worker in the photochemical and graphic arts.

It has hitherto been suggested to cause the light falling upon or reflected from an object to be copied, to fall upon a photo-tube, and to cause the current flowing through the tube to control the frequency of a suitable impulse discharge circuit. Since the current flowing through the photo-tube is proportional to the intensity of the light falling upon it, the frequency of the impulses or the interval between impulses becomes proportional to the light intensity; and if a desired exposure is based upon a given number of impulses, successive exposures may vary as to time duration, but will be constant as to light quantity. To this end counters actuated by the impulses through relays have been suggested.

It is an object of my invention to provide improved means for this purpose. It is a further object of my invention to provide improved apparatus which is independent of variations in factors other than the factor of light intensity. It is also an object of my invention to provide improved electrical circuits for such apparatus. Again it is an object of my invention to provide means whereby the frequency of the impulses for a constant light intensity may be more constant, and whereby the interval between the initial impinging of the light on the photo-tube and the first impulse will not be abnormally long, but will be the same or much more nearly the interval between subsequent impulses, assuming a constant intensity of light. Also it is an object of my invention to provide means whereby the integrating apparatus may be caused automatically to terminate the exposure as well as to give

a visible or audible signal. Still another object of my invention is to provide an assembly of apparatus of electrical character which may be actuated by the usual electrical current from the mains, and will be independent of variations in the line voltage.

These and other objects of my invention which will be set forth hereinafter or will be apparent to one skilled in the art upon reading these specifications, I accomplish by that certain construction and arrangement of parts of which I shall now set forth certain exemplary embodiments. Reference is made to the drawings in which:

Figure 1 is a simplified circuit diagram illustrating the principle of operation of my electrical means.

Fig. 2 is a circuit diagram indicating in addition one means for operating the circuit of Fig. 1 from a standard source of alternating current.

Fig. 3 is a circuit diagram showing the oscillatory means in a form preferred by me.

Fig. 4 is a representation of the means for effecting automatic operation of an exposure device such as the shutter of a camera, or means for controlling the light source.

Fig. 5 is a diagram of the control circuits.

The general features of my invention will be apparent from the ensuing description; and in the several drawings like parts have been given like index numerals.

In Figure 1, PT is a photo-tube having in series with it a source of E. M. F. shown as a battery B₁. The photo-tube circuit is completed by a condenser C₁; and it will be evident that current flowing through the tube in this circuit charges the condenser. Since the amount of current flowing in the circuit is proportional to the intensity of the light falling on the photo-tube, the charging rate of the condenser will be proportional to the said light intensity.

The condenser is arranged to discharge through a gaseous glow-discharge tube GT₁, preferably a triode tube with heated cathode. The anode or plate of the tube is connected directly with the positive side of condenser C₁; while the cathode of the tube is grounded through an inductance L and a resistance R₂. The condenser discharge circuit is completed by a connection between the negative side of the condenser C₁ and ground through a biasing battery B₂.

The grid of the tube GT₁ is connected through a resistance R₁ to the movable contact of a potentiometer P₁, which potentiometer is connected across the terminals of a source of E. M. F. indicated as a battery B₃. By these means the grid bias potential of the gaseous glow discharge tube GT₁ may be varied.

The operation of the circuit elements thus far described is as follows: When light falls on the photo-tube PT it becomes conductive, and battery B₁ is enabled to charge condenser C₁ at a rate depending upon the light intensity. The charging of the condenser proceeds at a rate varying with the light intensity until the condenser reaches a potential sufficient to initiate a discharge in the tube GT₁. The striking voltage of the gaseous glow discharge tube may be varied by controlling the grid bias of the tube by means of the potentiometer P₁. When the discharge voltage is reached, the condenser C₁ discharges through the plate-cathode circuit of the tube GT₁ (that is from plate to cathode). The discharge continues until the charge on C₁ falls to the extinction potential, whereupon the discharge

ceases. It will be clear that successive discharges occur in this circuit dependent as to interval upon the quantity of light falling upon the photo-tube; and that both general variations in light intensity and sporadic variations therein will vary the time intervals between discharges. Thus the number of impulses becomes a measure of the quantity of incident light.

The function of the battery B₂ in the circuit is to place the condenser C₁ initially at a voltage which is just slightly less than the arc breaking or extinction potential of the tube GT₁. Without voltage at B₂, the condenser C₁ would charge from zero potential to the striking potential of the tube GT₁, produce a discharge, fall to extinction potential, and then continue to fluctuate between these two potential values. The result is that the time interval between the starting of the apparatus and the initial discharge becomes abnormally long, because the condenser must be charged from zero to striking potential, whereas on succeeding impulses it does not fall to zero potential and therefore does not take as long to rise to striking potential, light intensity being assumed constant. By biasing the condenser C₁ with the battery B₂ or its equivalent, the interval between the start of the apparatus and the first impulse is made the same as or comparable to the intervals between succeeding impulses.

In the lead between the cathode of tube GT₁ and ground, I insert the inductance L and resistance R₂ as aforesaid. R₂ may be and preferably is variable for a reason which will be presently explained. I have found that the use of a choke or inductance L makes it possible for the condenser C₁ to discharge to a lower potential through the tube GT₁ than is possible with pure resistance. Further the combination of L and R₂ (where R₂ is variable or is varied) makes it possible to adjust the extinction potential, and hence the time interval between successive impulses, within rather wide limits. By way of example, without the use of battery B₂ or its equivalent, the voltage on condenser C₁ immediately after discharge through GT₁ has been varied from -15 volts to +60 volts in an exemplary device,—that is to say, the plate potential of GT₁ with respect to ground after discharge has been varied between -15 volts and +60 volts. This means of adjusting the time interval between impulses applies to all intervals following the first time interval after putting the device into operation. The length of the first time interval is adjusted, as explained, by the bias on the condenser C₁. The combination of the two adjustments is desirable in equalizing the time intervals, and the setting of these adjustment means holds for all positions of the sensitivity adjustment (which is the potentiometer P₁ and which varies the grid bias of the tube GT₁).

Still referring to Figure 1, GT₂ represents a second gaseous glow discharge tube of triode character. The cathode of this tube is directly grounded. The grid of the tube is connected through a resistor R₄ and a blocking condenser to the cathode of the tube GT₁. This connection may be made if desired to the cathode-to-ground circuit of tube GT₁ between the inductance L and resistance R₂ if desired, the object being to keep oscillations, arising elsewhere, out of the circuits of tube GT₁. I have not, however, found this necessary. The grid of tube GT₂ is also connected through the resistor R₄ and a resistor R₃ to the movable contact of a potentiometer

P₁, one end of which is grounded to complete the circuit. The resistance element of potentiometer P₂ shunts a battery B₅. Thus the grid bias of tube GT₂ may be adjusted.

5 The anode of tube GT₁ is connected through a magnet coil K and a source of alternating current G to ground. The magnet coil K is bypassed by a condenser C₃, which serves to prevent the coil from being actuated by each half-cycle pulse of direct current from the alternating source G, and also makes for steadier operation.

10 In operation, when a discharge occurs in tube GT₁, the voltage drop across the resistor R₂ and inductance L resulting from the flow of current through them, results in the impressing of a momentary positive voltage impulse. The normal grid bias on the tube GT₂ is so negative that no plate current can flow; but the momentary rise of the grid voltage to a less negative value permits the flow of plate current to energize the magnet coil K. For purposes of this discussion the magnet coil may be thought of as the coil of an electrically operated counter, an automatic timing means, or the energizing coil of a relay.

15 The tube GT₂ acts as a half-wave rectifier for the alternating current from source G, and permits the current to flow through the coil K only during the half-cycles when the plate of GT₂ is positive with respect to its cathode. The time constant of the grid circuit of the tube GT₂, which is determined by the values of capacity C₂, inductance L, resistors R₂ and R₃ and part of the resistance of potentiometer P₂, is such that the coil K is energized long enough to operate the counting mechanism. As soon as the voltage on the grid of GT₂ returns to its normal value, the flow of plate current through the magnet coil K ceases. The intervals between impulses in the discharge circuit of my system are very much longer than the time intervals represented by the frequency of 60-cycle alternating current, of course.

20 If D. C. voltage were applied to the circuit at the point G, after the occurrence of a discharge, the plate current would continue to flow after the return of the grid to normal voltage. With alternating current the complete cut-off of current through the tube GT₂ after each half cycle allows the grid to regain control and prevent further flow of plate current. It would be possible to use a source of direct current at G, but in this event means would have to be provided to drop the plate voltage below extinction potential after each impulse to allow the grid to regain control of the tube. One means of doing this comprises the use of two tubes in the place of the tube GT₂, with the plate of one of the tubes connected through the coil K to the source of plate voltage, the plate of the other tube being connected through a resistor to the plate supply, and with a condenser connected between the two plates.

25 Again, in the place of the gaseous discharge tube GT₂, a vacuum tube may be used, biased beyond cut-off except when impulses occur with the discharge of condenser C₁. In this case either A. C. or D. C. potential may be used on the plate of the tube.

30 Filament voltages for the tubes are indicated in Figure 1 as supplied by batteries B₄ and B₅.

35 Figure 2 shows an arrangement intended for use with alternating current voltage supply from city mains, but without a transformer. Like parts have been given like index numerals in this figure and will be readily recognized. In this circuit the power leads from the standard 120-

volt 60-cycle mains are so marked. C₅ is a condenser bridging the power leads and acting to prevent the most rapid line voltage surges from reaching the various circuits hereinabove described. All power represented by the various batteries of Figure 1 is supplied from the mains in Figure 2. The filaments of GT₁, GT₂ and the rectifier tube are in series and this series circuit through resistance R₅ is connected across the power leads. RT is an electronic rectifier tube, and C₄ is a filter condenser. The grid bias for GT₁ is derived through potentiometer P₁, and the grid bias for GT₂ is derived through potentiometer P₂. The positive bias on condenser C₁ is derived through a potentiometer P₃. These three potentiometers are all located in a circuit across the mains including the rectifier tube RT, the cathode of which is connected to the resistance R₅ through a tap P. In this modification the photo-tube PT has alternating current applied to it, but since a tube of this type is self-rectifying, the effect is essentially the same as though a direct current were used.

40 The arrangement shown in Figure 2, while satisfactory for certain uses, is sometimes affected by surges in line voltage. When lights or motors connected to the same mains are turned on or off, surges may enter the circuits of my invention, which surges may occasionally be of sufficient magnitude and of proper direction to cause the tube GT₂ to become conducting and register an impulse. Such spurious impulses happen most frequently when the charge on condenser C₁ is near the striking potential of tube GT₁ when only a small rise in voltage is sufficient to trip the circuit.

45 A circuit arrangement which provides against this contingency is shown in Figure 3. Here again the impulse circuits are the same and like indicia have been used for like parts. Ground connections are shown to the chassis of the instrument. A shield for the photo-tube is also shown. The mains are again indicated as before, and a somewhat more elaborate condenser system comprising C₆ and C₇ with an intermediate connection to ground is employed. A transformer T has its primary 5 fed from the mains through a voltage regulator VR, which may be a saturated-core transformer or other type of voltage regulation device. A so-called ballast tube may be employed, but is not so satisfactory since it allows a certain amount of variation and since it has an appreciable time lag. The transformer supplies power to all of the circuit elements while eliminating direct connection with the power lines. The transformer has a plurality of secondary windings and electrostatic shields between the windings, as indicated, to prevent electrostatic coupling between the circuits. A secondary 1 is connected, as indicated by broken leads X—X to the heater of the tube GT₁. A secondary winding 2 is connected to the heater of the rectifier tube RT and by broken leads Y—Y to the heater of tube GT₂. Still another secondary winding 3 is connected to the circuit of the rectifier tube which furnishes D. C. bias to the condenser C₁ and to the grids of the tubes GT₁ and GT₂. The last secondary winding 4 supplies current to the photo-tube PT, and is also connected to the plate circuit of the tube GT₂. The condensers C₈, C₉, and C₁₀ shown in Figure 3 are bypass condensers.

50 It may be pointed out that the potentiometers P₁ and P₃ provide a means for sensitivity adjustment.

The counter operated by the magnet coil K may be of various types. For practical purposes I prefer one which causes a single large hand to move around a dial, and for photolithography one revolution of the hand should correspond to about 200 impulses. A counter of this type enables the operator to watch the progress of an exposure from a distance. I provide means in connection with it for setting a predetermined exposure on the dial, and for cutting off lights or closing a camera shutter automatically. I have used a simple ratchet wheel with a pawl actuated by the magnet, and a simple contact means; but my preferred mechanism is shown somewhat diagrammatically in Figure 4. A magnet 5, which includes the coil K, operates an escapement mechanism indicated generally at 7. The escapement wheel is connected through a friction clutch 9 with a pinion 8 which meshes with a gear wheel 10. This gear wheel bears the pointer 11 which moves over the scale 12, only part of which is shown.

The gear wheel 10 meshes with the teeth of a gear wheel 13 which is somewhat larger than 10. A clock spring 14 is connected at one end to the shaft 15 of the gear wheel 13 and at the other to a fixed support 16. An arm 17 on the shaft 15 is arranged to actuate a switch 18 when the pointer 11 is at zero. The pointer may be reset for a new exposure by means of the setting knob 19, the friction clutch permitting this. The scale may be calibrated as desired; and the pointer is set at a desired exposure, and during the operation of the device moves counter-clockwise over the scale toward zero. Resetting the pointer winds the spring; and the magnet-operated escapement releases the spring energy at a rate determined by the light intensity.

A control circuit for convenient operation is shown in Figure 5. A four-circuit relay is employed, the coil 20 of which may be connected to the power mains indicated. In this circuit in series, however, I provide a normally open START button and a normally closed STOP button (so marked). The switch 18 which is operated by the counter mechanism is in a holding circuit shunting the START button. The holding circuit contacts of the relay are indicated at 21. When the counter is set the switch 18 is closed as respects the holding circuit; but the holding circuit remains open until the relay is actuated, which is done by pressing the START button. Thereafter the holding circuit maintains the relay closed though the START button be released, until the counter mechanism actuates the switch 18 to break the circuit.

Relay contacts indicated at 22 (closed when the relay is closed) are located in the circuit, not shown, which is employed to operate the arc lamps or the camera shutter. Contacts 23 (open when the relay is closed) are located in a shorting circuit for the condenser C₁. This circuit contains a high resistance R₄ in Figure 3, and the connections are indicated at a-a. When the condenser is shorted the impulse circuits cannot function; so that the relay acts as starting and stopping means for the impulse circuits. Relay contacts 24 (closed when the relay is closed) may be located in a circuit to operate a dial light or other visible signal. The switch 18, if it is a double throw switch, may be made to operate an alarm circuit, so marked.

In operation, as will be clear, the pointer 11 is first set at the desired exposure. When the exposure is to begin, the START button is pressed

and released. The relay acts to turn on the lights or open the camera shutter as the case may be. Simultaneously it breaks the circuit shorting the condenser C₁, and starts the integrating impulse action. The pointer then travels toward zero in accordance with the light intensity. When it reaches zero the switch 18 breaks the holding circuit of the relay and stops activity in all circuits except the alarm circuit. However, if it is desired to stop the action before the pointer reaches zero this may be done by pressing the STOP button.

It will be understood that the apparatus will be housed in a suitable cabinet or cabinets, and that the photo-tube may be made movable to facilitate its use.

Modifications may be made in my invention without departing from the spirit of it. Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In a device of the character described a photo-tube having a circuit, a source of potential and a capacity in said circuit, a gaseous glow discharge tube of the three element type having a grid-to-cathode circuit, biasing means in said circuit whereby the striking potential of said tube may be determined, said tube also having an anode-to-cathode circuit containing said capacity, said circuit forming a discharge circuit in which a discharge will occur when said capacity is charged to the striking potential of said tube, so that said discharges occur at intervals inversely proportional to the intensity of light falling upon said photo-tube, means in said last mentioned circuit for biasing said capacity nearly to the extinction potential of said tube so that the interval between setting the circuits into operation and the first discharge becomes more nearly equal to the intervals between subsequent discharges, and means for deriving impulses from said discharge circuit to actuate a counter.

2. In a device of the character described, a photo-tube having a circuit, a source of potential and a capacity in said circuit, a gaseous glow discharge tube of the three element type having a grid-to-cathode circuit, biasing means in said circuit whereby the striking potential of said tube may be determined, said tube also having an anode-to-cathode circuit containing said capacity, said circuit forming a discharge circuit in which a discharge will occur when said capacity is charged to the striking potential of said tube, so that said discharges occur at intervals inversely proportional to the intensity of light falling upon said photo-tube, means in said last mentioned circuit for varying the extinction potential of said discharge tube, and means for deriving impulses from said discharge circuit to actuate a counter.

3. In a device of the character described, a photo-tube having a circuit, a source of potential and a capacity in said circuit, a gaseous glow discharge tube of the three element type having a grid-to-cathode circuit, biasing means in said circuit whereby the striking potential of said tube may be determined, said tube having also an anode-to-cathode circuit containing said capacity, said circuit forming a discharge circuit in which a discharge will occur when said capacity is charged to the striking potential of said tube, so that said discharges occur at intervals inversely proportional to the intensity of light falling upon said photo-tube, means in said last mentioned circuit for varying the extinction potential of said discharge tube, said

means comprising an inductance and a resistance in series, and means for deriving impulses from said discharge circuit to actuate a counter.

4. In a device of the character described, a photo-tube having a circuit, a source of potential and a capacity in said circuit, a gaseous glow discharge tube of the three element type having a grid-to-cathode circuit, biasing means in said circuit whereby the striking potential of said tube may be varied, said tube also having an anode-to-cathode circuit containing said capacity, said circuit forming a discharge circuit in which a discharge will occur when said capacity is charged to the striking potential of said tube, so that said discharges occur at intervals inversely proportional to the intensity of light falling upon said photo-tube, means in said last mentioned circuit for biasing said capacity nearly to the extinction potential of said discharge tube so that the interval between setting the circuits into operation and the first discharge becomes more nearly equal to the intervals between subsequent discharges, means in said last mentioned circuit for varying the extinction potential of said discharge tube, said means comprising an inductance and resistance in series, and means for deriving impulses from said discharge circuit to actuate a counter.

5. In a device of the character described, a gaseous glow discharge tube having a discharge circuit, a capacity in said discharge circuit, a source of potential for charging said capacity and a photo-tube in series therewith to render the rate of charge proportionate to the intensity of light falling upon said photo-tube, and means for deriving impulses from said discharge circuit for actuating a counter, said means comprising a second glow discharge tube, said tube being of the three element type, a grid-to-cathode circuit therefor containing means for biasing said tube to cut-off, a connection between said circuit and the cathode of said first mentioned tube, and an anode-to-cathode circuit for said second tube containing a source of alternating current and the magnetic coil of said counter.

6. Apparatus as claimed in claim 5 including a capacity shunting said magnetic coil.

7. In a device of the character described, a photo-tube having a circuit, a source of potential and a capacity in said circuit, a gaseous glow discharge tube of the three element type having a grid-to-cathode circuit, biasing means in said circuit whereby the striking potential of said tube may be varied, said tube having also an anode-to-cathode circuit containing said capacity, said circuit forming a discharge circuit in which a discharge will occur when said capacity is charged to the striking potential of said tube, so that said discharges occur at intervals inversely proportional to the intensity of light falling upon said photo-tube, means in said last mentioned circuit for biasing said capacity nearly to the extinction potential of said discharge tube so that

the interval between setting the circuits into operation and the first discharge becomes more nearly equal to the intervals between subsequent discharges, means in said last mentioned circuit for varying the extinction potential of said tube and comprising an inductance and resistance in series, and means for deriving impulses from said discharge circuit to actuate a counter, said last mentioned means comprising a second glow discharge tube, said tube being of the three element type, a grid-to-cathode circuit therefor containing means for biasing said tube to cut-off, a connection between said circuit and the cathode of said first mentioned discharge tube, and an anode-to-cathode circuit for said second discharge tube containing a source of alternating current and the magnet coil of said counter.

8. Apparatus as claimed in claim 7 arranged for actuation from alternating current mains and comprising a rectifier tube, a connection across said mains including the heaters of the discharge and rectifier tubes, a connection across said mains including the anode and cathode of said rectifier tube and a plurality of potentiometers, means for deriving biasing potentials for said first mentioned discharge tubes and for said capacity from said potentiometers severally, and alternating current connections to said photo-tube and to the plate circuit of said second mentioned discharge tube.

9. Apparatus as claimed in claim 7 arranged for actuation from alternating current mains and comprising a rectifier tube, a connection across said mains including the heaters of the discharge and rectifier tubes, a connection across said mains including the anode and cathode of said rectifier tube and a plurality of potentiometers, means for deriving biasing potentials for said first mentioned discharge tubes and for said capacity from said potentiometers severally, alternating current connections to said photo-tube and to the plate circuit of said second mentioned discharge tube, and at least one filter condenser in connection with one of said circuits for minimizing surges.

10. Apparatus as claimed in claim 7 arranged for actuation from alternating current mains and comprising a rectifier tube, a voltage regulator and a transformer having a primary, a secondary winding on said transformer for supplying alternating current to said photo-tube and to the plate circuit of the second of said discharge tubes, secondary windings for supplying alternating current to the heaters of the several tubes, and a secondary winding in the circuit of said rectifier tube, said circuit containing potentiometers, means for deriving biasing potentials from said potentiometers.

11. Apparatus as claimed in claim 7 including means in connection with said counter for short-circuiting said capacity when operation of said circuits is not desired.

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