Sept. 26, 1939. A. J. McMASTER ET AL 2,174,500

ELECTRIC GLOW VALVE SYSTEM

Filed Sept. 5, 1936 2 Sheets-Sheet 1

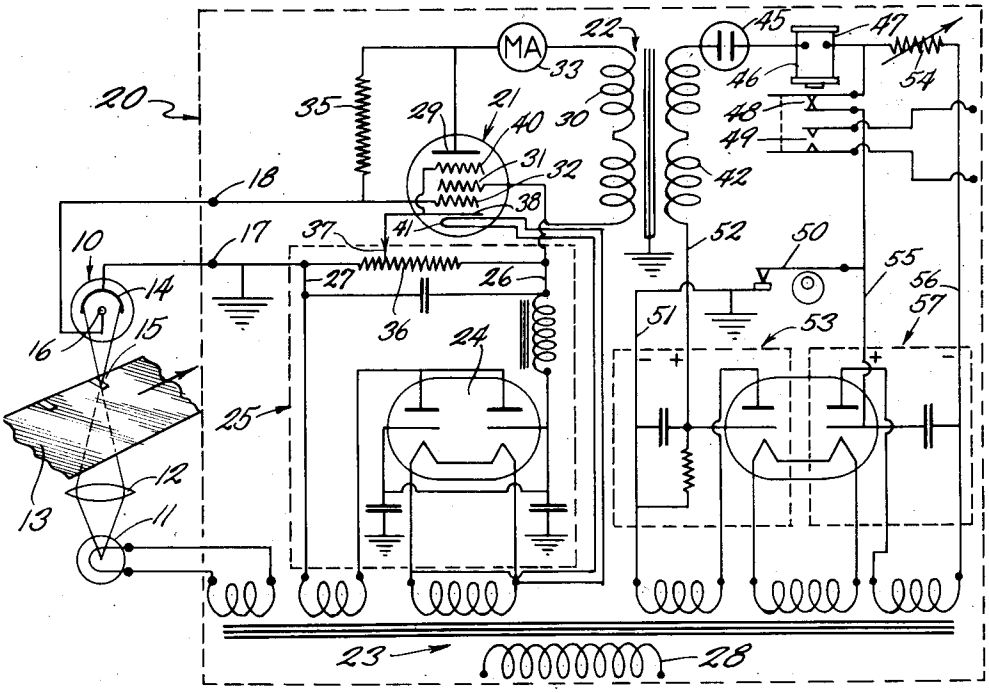


Fig. 1.

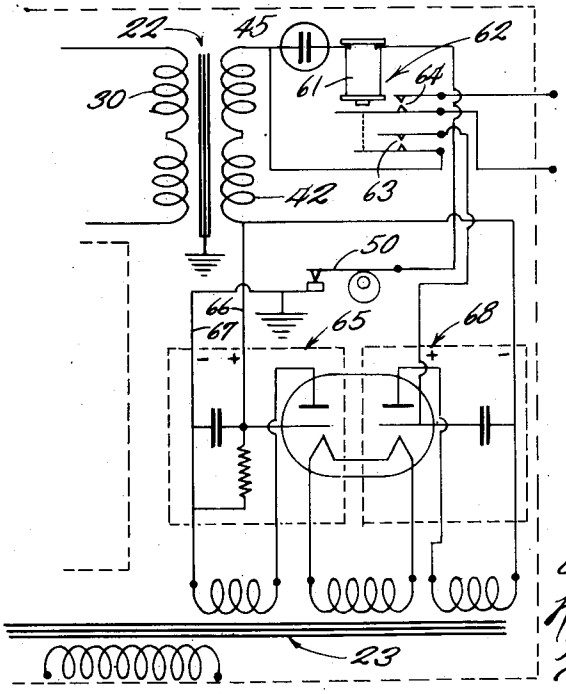


Fig. 2.

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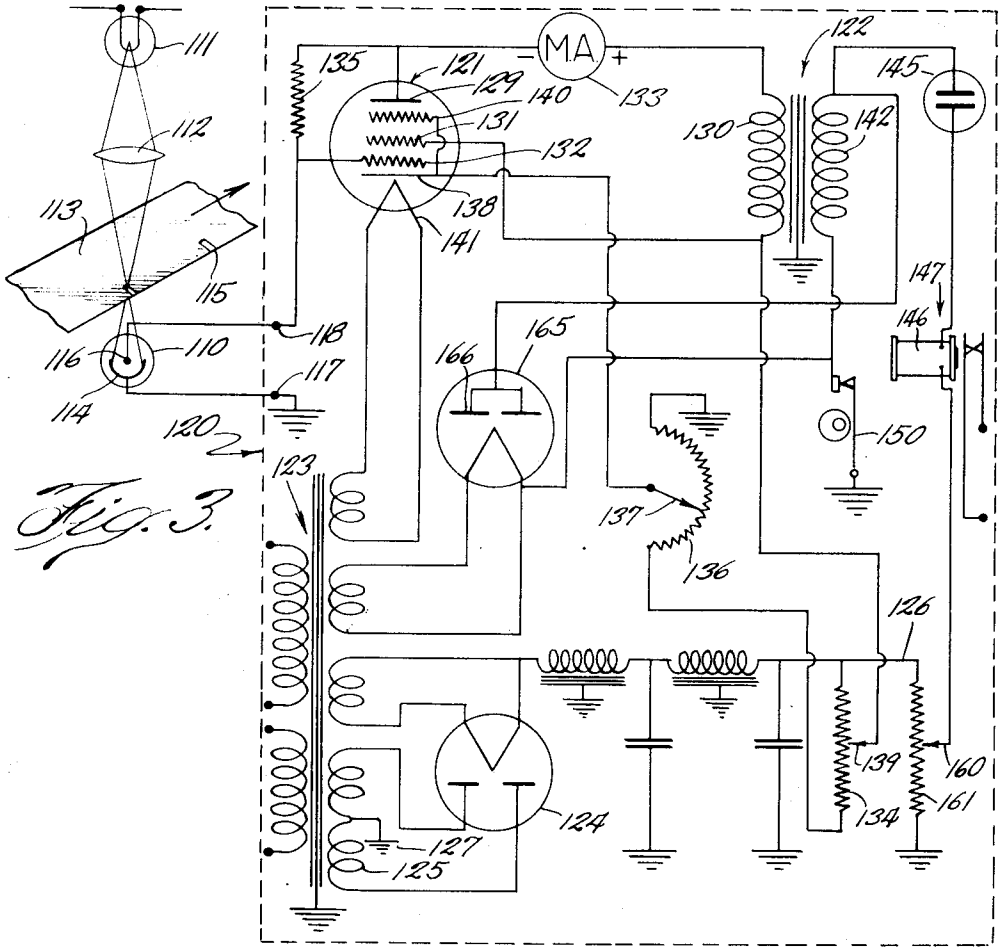


Fig. 3.

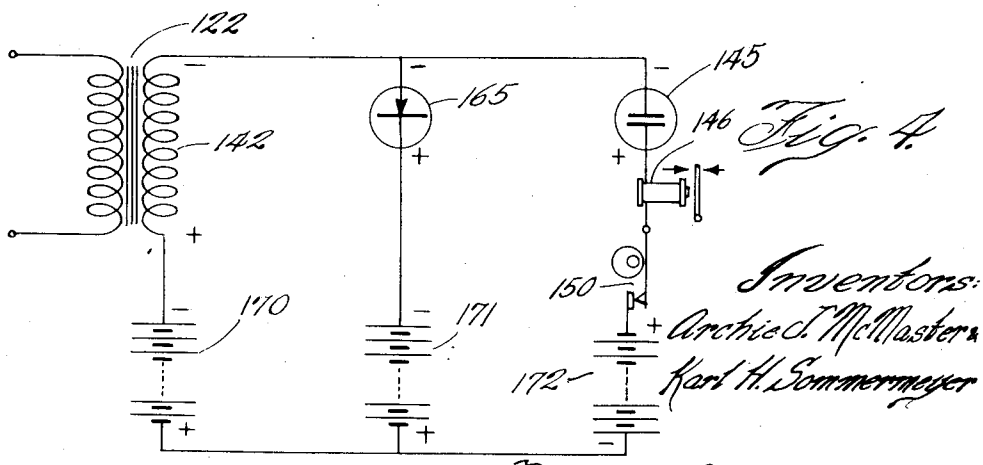


Fig. 4.

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ELECTRIC GLOW VALVE SYSTEM

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Application September 5, 1936, Serial No. 99,674

16 Claims. (Cl. 250—27)

Our present invention relates generally to electric control systems and relates more particularly to systems employing glow valves or the like, especially, diode glow valves.

A glow valve is a space discharge device and generally consists of two or more electrodes immersed in a gaseous medium contained within a suitable inclosure for confining the gas thereof at a suitable pressure.

A glow valve is so called because its gas emits an iridescent glow when current is conducted therethrough between the electrodes. The current passed by such a valve is conducted therethrough by a flow of gaseous ions in the interelectrode space, the gas being under a condition of sustained ionization. When the current is interrupted the gas deionizes by recombination of ions except for a small degree of ionization known as the residual ionization. In this idle condition the valve exhibits a high impedance because there are not sufficient ions present to produce an appreciable current. When the voltage across the electrodes is raised to a sufficiently high value, known as the striking voltage, the voltage gradient in the interelectrode space becomes so high that the rate of ionization by collision resulting from the presence of residual ions exceeds the rate of accidental recombination and a condition of sustained operation is precipitated. This is accompanied by the initiation of a substantial current and its concomitant glow and therefore by a reduction of the impedance of the valve. It is a condition of sustained ionization, or sustained glow operation, of the valve and when established, that condition can be maintained at a voltage considerably less than the ignition voltage defined above. The lower limit of the range of voltages at which glow operation will be maintained is known as the extinguishing voltage. Obviously the extinguishing voltage is lower than the ignition voltage. When the voltage impressed across the electrodes drops below the extinguishing value, the rate of ionization falls below the rate of recombination of ions and the valve ceases to pass current. That is, its glow operation is interrupted, and its impedance returns to a high value. A glow valve will ignite upon receiving high voltage for a very short period of time and thereafter will maintain its operation if a voltage above its extinguishing voltage, is maintained.

Glow valves frequently are employed in systems where it is desired to prolong the effect of an electric disturbance, impulse or signal. Thus a brief or transient signal may serve to ignite a valve which thereafter continues to glow so as to operate a relay or the like which requires a period of time for its operation far in excess of the duration of the signal.

For example, a glow valve may be employed to advantage with photoelectric register control equipment in which a photoelectric cell is illuminated by light reflected from, or transmitted through, a moving web of strip material, such as paper, and in which printed reference marks coming periodically into the light beam induce signals in the photoelectric cell. These signals may be amplified and also "timed" by an interrupter to determine whether the strip material is in proper register with the machine through which it is passing. The signals ignite the glow valve to control the adjustments necessary to bring the material into register. This serves to keep successive printing operations, or printing and cutting operations or the like in proper register with each other.

The most advantageous amplification of a signal for the purpose of igniting a glow valve usually requires a coupling arrangement between the amplifier and glow valve such that a high impedance is presented thereby to the glow valve. Heretofore this has proven to be a disadvantage in the operation of glow valves of the diode type since, in systems heretofore known, the diode glow valves were required to pass their glow currents through their signal input devices. A diode glow valve, while it lacks the inherent high sensitivity and self amplification of a grid controlled glow valve, does possess a greater degree of stability and in that respect is superior to the grid controlled type for certain uses. While the present invention is particularly directed to the improvement of systems employing diode glow valves, it, also, may be used under certain conditions with other types of glow valves.

It is a primary purpose of the present invention to provide an improved system for the control of a glow valve by an electronic amplifier for the operation of a relay or the like.

It is a further object to provide a simple and cheap, but efficient and reliable glow valve system.

It is a further object to increase the effectiveness of a signal for igniting a glow valve by subjecting it to voltage amplification in a high ratio transformer.

It is a further object of our invention to improve the operation of a glow valve for the control of a magnetic relay or the like by altering

its circuit conditions in response to the ignition of the valve so as to permit a greater glow current to flow than can flow under those conditions which permit a reliable and sensitive control of the ignition of the valve.

It is a still further object of our invention to provide means other than the valve itself which will be responsive to the glowing of the valve for increasing the voltage-to-impedance ratio of the circuit containing the anode and cathode of the valve.

It is a still further object of our invention to provide means for separately adapting the circuit of a diode glow valve to each separate function which it is required to perform so that the valve operates to its best advantage both when receiving a signal for its ignition and when glowing to operate a relay or the like.

A further object is the provision of an improved system embodying a glow valve.

These and other objects and advantages will appear as the description proceeds.

In order better to acquaint those skilled in the art with the teachings and the practice of our present invention, we now shall describe certain specific embodiments thereof, reference being had to the accompanying drawings which form a part of this specification, and in which: Figs. 1 and 2 are circuit diagrams of photoelectric amplifier and relay systems employing diode glow valves and embodying our present invention; Fig. 3 illustrates a similar system embodying our present invention in its preferred form; and Fig. 4 illustrates a modification of the system of Fig. 3.

In Fig. 1, a photoelectric cell **10** is illuminated by a lamp or light source **11**. The light from the lamp **11** is focused by a lens **12** into the plane of a moving web of strip material **13**, the light passing therethrough to irradiate the light sensitive cathode **14** of the photoelectric cell **10**. The web **13** carries a series of relatively opaque reference marks **15** which are so arranged as to pass into the light beam as the strip progresses so as to diminish or substantially interrupt the illumination of the cathode **14** of the photoelectric cell **10**. The cathode **14** and anode **16** of the photoelectric cell are connected to the in-put terminals **17** and **18** respectively of an amplifier and relay unit indicated generally by the reference numeral **20**. The amplifier comprises a pentode amplifying valve **21** coupled to an impulse transformer **22**.

Power for the operation of the entire system including the pentode **21** of the amplifier is obtained from a transformer which is designated generally by the reference numeral **23** and which has a primary winding **28**. The system of Fig. 1 preferably includes three separate power supplies having rectifiers and filters all powered by the transformer **23**. The power supply for the pentode valve **21** is designated generally by the reference numeral **25** and includes a diode rectifier valve **24** and a conventional filter net. The positive terminal of the out-put of the power supply **25** is designated by the reference numeral **26** and the negative terminal thereof by the reference numeral **27**. The anode **29** of the pentode amplifying valve **21** is connected to the positive terminal **26** of the power supply **25** through the primary winding **30** of the impulse transformer **22** and a milliammeter **33**. The screen grid **31** of the pentode **21** is connected directly to the terminal **26** so that it remains at substantially constant potential for shielding the control grid **32** from the effect of varying potentials of the anode **29** in a manner well known in the art.

A high resistance **35** is connected in series with the photoelectric cell **10** between the negative terminal **27** of the power supply and the anode **29** of the valve **21** to supply to the photoelectric cell the voltage required for its operation, the cathode **14** of the photoelectric cell being connected to terminal **27** and the anode **16** thereof being connected to the resistor **35**. The anode **16** of the photoelectric cell is connected, also, to the control grid **32** of the pentode amplifier **21**. A bleeder **36** is connected across the terminals **26** and **27** of the power supply **25**; and a tap **37** of the bleeder is connected to the cathode **38** of the amplifier **21**. An adjustment of the tap **37** of the bleeder **36** serves to control the difference of potential between the cathode **38** and control grid **32** of the valve. This is commonly referred to as the bias potential of the valve. The tap **37** should be adjusted to provide a low anode current as indicated by the milliammeter **33** when no reference mark **15** obstructs the beam of light focused on the photoelectric cell **10**. Thus if the valve **21** saturates at about **15** milliamperes, the current may be set at 1 milliampere. When one of the reference marks **15** darkens the cell **10**, the anode current of the valve **21**, as shown by meter **33** will increase.

A "cathode grid" **40** which serves to suppress secondary emission from the anode **29** in valve **21** is connected directly to the cathode **38** within the valve itself. A filament heater **41** for the cathode **38** of the valve **21** receives power from one of the windings of the transformer **23**.

The impulse transformer **22** has an exceedingly high step-up ratio. It is desirable to secure as much signal amplification as possible in the transformer **22** and to this end it is given as high an impedance ratio as is possible. As is well known, the impedance that may be provided in such a winding is limited in part by the presence of capacity between the individual turns of the winding.

The secondary winding **42** of the transformer **22** is connected in series with a diode glow valve **45**, the coil **46** and contacts **48** of a relay **47**, a timer or interrupter **50** and a power supply **53** having terminals **51** and **52**. Shunting the contacts **48** of the relay **47**, is a circuit through a resistor **54** and a power supply **57** having terminals **55** and **56**. Additional contacts **49** of the relay **47** are provided for the purpose of controlling a load circuit in any known manner. Each of the power supplies **53** and **57** includes a secondary winding of the transformer **23**, a diode rectifier, and a filter net. The two diode rectifiers of the power supplies **53** and **57** are represented as being within a common envelope.

The operation of the system of Fig. 1 is as follows: The voltage between the terminals **51** and **52** is arranged to be less than the ignition voltage of the diode glow valve **45** but in excess of the extinguishing or minimum operating voltage thereof. The interrupter **50** periodically opens and closes the circuit through the glow valve **45**. The web **13** continually passes through the beam of light which illuminates the cathode **14** of the photoelectric cell **10**, and in so doing suddenly interrupts a substantial portion of the light flux each time that one of the reference marks **15** enters the light beam. This sudden change of illumination controls the amplifier valve **21** to produce a sudden change in its plate current or anode current which flows through the

primary winding 38 of the impulse transformer 22. This sudden change of primary current of the transformer produces a high voltage signal in the secondary winding 42; and if the interrupter 50 is closed at the time of the signal, the signal is impressed across the glow valve 45. This signal either adds to or subtracts from the voltage appearing at the terminals 51 and 52 depending upon the relative polarities of the various connections of the circuit.

As the reference mark 15 leaves the light beam, the light flux incident on the photoelectric cell suddenly increases and acts through the amplifier 21 and transformer 22 to impress another signal on the glow valve of a polarity opposite to that of the first signal.

One of these two signals will be of the proper polarity to add itself to the voltage appearing at the terminals 51 and 52 of the power supply 53. The voltage of the signal is of sufficiently high value that when it is added to the voltage of the power supply 53 the total voltage impressed across the electrodes of the diode glow valve 45 is sufficient to ignite the valve. That is, it is sufficient to initiate a sustained glow operation of the valve 45. Immediately that the tube 45 begins to glow, current traverses the coil 46 of the relay 47 causing the relay to operate.

Because of the necessarily high impedance of the secondary winding 42 of the transformer 22, and because it is necessary to limit the voltage of the power supply to some value below the ignition voltage of the valve 45, the current which initially passes through the relay coil 46 when the valve 45 glows, is limited. As soon as the relay 47 begins to operate, it opens its contacts 48 so that the current of the valve 45 flows through the resistor 54 and the power supply 57. This places the two power supplies 53 and 57 in series in the glow valve circuit with their voltages adding. It, also, adds the resistance 54 to the glow valve circuit. The voltage of the power supply 57 may be as high as necessary for supplying sufficient current for satifactory operation of the relay 47. The resistor 54 need have only a high enough resistance to avoid drawing too much power from the power supply 57 when the contacts 48 are closed.

If the voltage-to-resistance ratio of the power supply 57 and resistor 54 is higher than the voltage-to-resistance ratio of the power supply 53 and its circuit (including the glow valve 45, but not including the power supply 57 or resistor 54) the opening of the contacts 48 of the relay 47 serves to increase the voltage-to-resistance ratio of the circuit containing the glow valve 45. An increase of this ratio increases the current through the glow valve and coil 46.

The extra current supplied in this manner to the coil 46 hastens the further operation of the relay 47. The next subsequent opening of the interrupter or timer 50 opens the circuit through the coil 46 and the glow valve 45 so as to interrupt the current therethrough. This extinguishes the glow valve and deenergizes the coil 46 of the relay 47. The relay, therefore, "releases" and in so doing again closes the contacts 48. This removes the potential of the power supply 57 from the circuit through the glow valve 45 so that upon a subsequent closing of the interrupter 50, the potential of the power supply 57 will not be impressed upon the glow valve 45. As a result of the operation of the relay 47, the load contact 49 has closed and opened its load circuit to effect the desired control function. Should a signal be transmitted from the photoelectric cell 10, at a time when the contacts of the interrupter 50 are open, it will be ineffective to ignite the glow valve 45.

It is not necessary to describe here the complete control scheme for controlling the register of the strip material 13 with respect to the operation of the interrupter 50 since the general arrangement of such control schemes is well known and the same forms no part of our present invention. The control apparatus used with our system just described, should be arranged to so operate in response to the operation of the contacts 49 as to advance the strip 13 with respect to the operation of the interrupter 50. The strip 13 should be arranged normally to run slightly slow so that it lags behind the operation of the interrupter 50 and requires an occasional advance to keep it in register. This causes the apparatus of the present invention to "time" the movement of the strip material 13 with respect to the closing operation of the interrupter 50. The interrupter 50 should be driven synchronously, as by means of gears or the like, with that part of the processing machine with which it is desired to register the separate impressions or the separate gauge marks 15 of the strip material 13. In Fig. 2 we have illustrated a slightly different photoelectric glow valve system embodying our present invention. The photoelectric cell and its amplifier in the system of Fig. 2 are identical with the corresponding apparatus of the system of Fig. 1, and therefore are not shown fully in Fig. 2. The corresponding parts are indicated by the same reference numerals. In Fig. 2, the secondary winding 42 of the impulse transformer 22 is connected in series with the diode glow valve 45, the coil 61 of a relay 62, the interrupter 50 and a power supply 65 having a positive terminal 66 and a negative terminal 67. A shunt circuit comprising the normally open contact gap 63 of the relay 62 and the power supply 68 is connected across the terminals of the secondary winding 42 of the impulse transformer 22. The polarity of the power supply 68 is such with respect to that of the power supply 65 that their voltages add in the series circuit through them both, which circuit is established when the contacts 63 close. Load contacts 64 operated by the relay 62 may be connected to other apparatus for controlling it in a known manner. Each of the power supplies 65 and 68 includes a diode rectifier and a filter net.

In operation, the photoelectric cell and its amplifier, (not shown in Fig. 2) operate in the same manner as do the corresponding pieces of apparatus of Fig. 1 to produce a series of high-voltage signals in the secondary winding 42 of the impuse transformer 22. If a signal of the proper polarity for adding itself to the voltage of the power supply 65, is produced when the interrupter 50 is closed, the glow valve 45 ignites. A weak flow of current driven by the voltage of the power supply 65 traverses the glow valve 45 and the coil 61 of the relay 62. This causes the relay 62 to begin its operation, whereupon it closes its contacts 63 to close the shunt path around the secondary winding 42 of the transformer 22. This permits the current through the glow valve 45 to bypass the comparatively high resistance of the winding 42 by flowing through the low resistance of the shunt path established by the closing of the contacts 63. This serves to lower the resistance of the glow valve circuit, and also to add thereto the

voltage of the power supply 68 to aid that of the power supply 65. Either of these effects alone would serve to increase the current flowing through the valve 45 and the relay coil 61. The two effects together permit the current to be increased to the full capacity of the valve 45. This increased current hastens the operation of the relay 62. Thereafter, the interrupter 50 opens its contacts so as to terminate the glow operation. This deenergizes the coil 61 of the relay 62 causing it to "release", and in so doing to open its contacts 63. This restores the coupling of the valve to its signal input (the winding 42 of the impulse transformer 22) so that a subsequent signal produced at a time when the contacts of the interrupter 50 again are closed will produce another glow operation of the valve 45. The relay 62, in operating, has closed and opened its load contacts 64 to control its load circuit.

It is to be observed that the contacts 63 of the relay 62, in establishing the shunt circuit across the signal input of the valve 45 (the winding 42), served to remove from the glow current circuit a comparatively high resistance and to add thereto additional voltage so as to materially increase the voltage-to-resistance ratio thereof. Obviously the power supply 68 may be omitted and the contacts 63 employed merely to short circuit the winding 42. Merely removing this high resistance from the glow valve circuit produces an increase of the voltage to resistance ratio of the glow valve circuit.

The system of Fig. 1 may be preferred under certain conditions to the system of Fig. 2 because it employs normally closed contacts (contacts 48) to provide the "current boosting" function. In certain types of relays, normally closed contacts can be made to operate on a slight initial motion of the relay armature more easily than can normally open contacts.

Under other conditions the system of Fig. 2 may be preferred because it actually removes the major high resistance, namely the transformer winding, from the glow valve circuit, and therefore permits a greater voltage resistance ratio with the same total voltage in the two power supplies. In fact, this provides ample current in many instances without the use of the power supply 68.

Fig. 3 illustrates the preferred embodiment of our present invention. Therein, a photoelectric cell 110 is illuminated by a lamp or light source 111. The light from the lamp 111 is focused by a lens 112 into the plane of a moving web of strip material 113, the light passing therethrough to irradiate the light sensitive cathode 114 of the photoelectric cell 110. The web 113 carries a series of relatively opaque reference marks 115 which are so arranged as to pass into the light beam as the strip progresses so as to diminish or substantially interrupt the illumination of the cathode 114 of the photoelectric cell 110. The cathode 114 and anode 116 of the photoelectric cell are connected to the in-put terminals 117 and 118 respectively of an amplifier and relay unit indicated generally by the dotted outline 120. Terminal 117 is grounded to the chassis. The amplifier comprises a pentode amplifying valve 121 coupled to an impulse transformer 122.

Power for the operation of the entire system including the pentode amplifier is obtained from a transformer which is designated generally by the reference numeral 123. The power supply comprises a full wave rectifier 124, a tapped secondary winding 125 of the transformer 122 and a conventional filter net. The positive terminal of the out-put of the power supply is designated by the reference numeral 126 and the negative terminal is grounded at 127. Connected between the positive terminal 126 of the power supply and ground are a pair of series connected resistors 134 and 136 which constitute a bleeder. These resistors have taps 139 and 137 respectively to permit an adjustment of the potentials supplied to the amplifying valve 121. The anode 129 of the pentode amplifying valve 121 is connected to the tap 139 of the resistor 134 through the primary winding 130 of the impulse transformer 122 and a milliammeter 133. The screen grid 131 of the pentode 121 is connected directly to the tap 139 so that it remains at substantially constant potential for shielding the control grid 132 from the effect of varying potentials of the anode 129 in a manner well known in the art.

A high resistance 135 is connected in series with the photoelectric cell 110 between ground and the anode 129 of the valve 121 to supply to the photoelectric cell the voltage required for its operation, the cathode of the photoelectric cell being connected to terminal 127, and the anode 116 thereof being connected to the resistor 135. The anode 116 of the cell is connected, also, to the control grid 132 of the pentode amplifier 121. The tap 137 of the bleeder resistor 136 is connected to the cathode 138 of the amplifier 121. An adjustment of the tap 137 of the bleeder resistor 136 serves to control the difference of the potential between the cathode 138 and control grid 132 of the valve. This is commonly referred to as the bias potential of the valve. The tap 137 should be adjusted to provide a low anode current as shown by the milliammeter 133 when the light beam is unobstructed by any of the reference marks 115. Thus if the pentode valve 121 saturates at a current in the neighborhood of 15 milliamperes, the tap 137 may be set to bring this current to about 1 milliampere. When one of the reference marks 115 darkens the photoelectric cell 110, the anode current of the valve 121 will increase.

A "cathode grid" 140 of the valve which serves to suppress secondary emission from the anode 129 in valve 121 is connected directly to the cathode 138 within the valve itself. A filament heater 141 for the cathode 138 of the valve 121 receives power from one of the windings of the transformer 123.

The impulse transformer 122 has an exceedingly high step-up ratio. It is desirable to secure as much signal amplification as possible in the transformer 122 and to this end it is given as high an impedance ratio as is possible. As is well known, the impedance that may be provided in such a winding is limited in part by the presence of capacity between the individual turns of the winding.

The secondary winding 142 of the transformer is connected in a circuit which may be traced as follows: Beginning at the ground connection at an interrupter 150, through the contact gap of the interrupter 150, thence through the winding 142 of the transformer 122, thence through a diode glow valve 145 and the coil 146 of a relay 147 to the power supply. The connection to the power supply is made at an adjustable tap 160 of a bleeder 161 to permit an adjustment of the voltage which is impressed across the glow valve 145 during its idle or non-glowing period. The circuit is completed through the ground connection of the power supply. The glow valve 145 is

of the cold cathode type. An electronic rectifier 165, such as a diode having a hot cathode and containing mercury vapor, is shunted across the terminals of the secondary winding 142 of the impulse transformer 122, its anode 166 being connected to that terminal of the winding 142 which faces the positive terminal of the power supply in the circuit through the glow valve 145 so that a substantial portion of the current from the power supply that passes through the glow valve 145 will be shunted around the winding 142 through the rectifier 165. It is to be observed that the system is so arranged as respects the polarity of the power supply and as respects the respective locations of the timer 150, transformer winding 142, glow valve 145 and relay coil 146 in the glow valve circuit as to impose a minimum shunt capacity across the terminals of the winding 142. Thus, inasmuch as one terminal of the transformer winding 142 is connected to ground through the interrupter 150, precaution is taken to avoid connecting to the other terminal of the winding 142, any object having a high capacity to ground, such as for example, the cathode of the valve 165 which is connected to a secondary winding of the transformer 123. The ungrounded terminal of the transformer winding 142 is connected only to the anode of the rectifier 166 and the cold cathode of the glow valve 145 both of which have comparatively low capacities to other elements of the apparatus. If a glow valve having a hot cathode requiring heater connections to the transformer should be employed, it would be desirable to use a rectifier shunting the winding 142 having a cold cathode, and to connect the anode of the glow valve and the cathode of the rectifier to the ungrounded terminal of the transformer winding 142, the power supply connections being changed to suit. The contacts 148 of the relay 147 are arranged to be operated in response to the flow of current through the coil 146 when valve 145 glows. These contacts may be connected to control a load circuit in any known manner for providing the desired control function.

In operation, the photoelectric cell 110 generates a signal each time that one of the reference marks 115 of the strip 113 enters or leaves the beam of light from the light source 111, which is focused to illuminate the cathode 114 of the photoelectric cell 110 through the web 113. The signal generated by the photoelectric cell in response to each of the reference marks 115 entering the light beam will be amplified by the pentode valve 121 and will produce an abrupt increase of current in the primary winding 130 of the transformer 122. The signal produced in photoelectric cell 110 when each reference mark 115 leaves the light beam, will produce an abrupt decrease in the current in the winding 130.

These abrupt changes in the primary current of the transformer 122 produce high voltage signals in the secondary winding 142 thereof, having opposite polarities. Both of these signals will tend to impress voltages across the terminals of the glow valve 145. One of these signals will be in such direction as to oppose the voltage of the power supply and will tend to reduce the voltage impressed across the electrodes of the glow valve 145. This signal will encounter a low impedance through the rectifier 165 which shunts the secondary winding 142. The other signal, being of opposite polarity, will add itself to the voltage of the power supply so as to increase the total voltage impressed upon the electrodes of the glow valve 145. This signal encounters the high impedance of the rectifier 165, and since the rectifier 165 is of the electronic type, none of the signal current passes therethrough. Consequently the full signal strength is available to be impressed across the terminals of the glow valve 145. The sum of the signal voltage and the voltage of the power supply is sufficient to ignite the valve 145, that is to initiate its glow operation, and once the glow is initiated, it becomes self-sustaining at voltages considerably below that required for ignition. The voltage of the power supply is less than the ignition voltage but is sufficient by itself to maintain the glow operation of the valve 145. That is, the voltage of the power supply is in excess of the extinguishing voltage of the glow valve 145. Once the valve 145 begins to glow the power supply will maintain the glow operation without the aid of the signal so that the glow persists after the termination of the signal. The current flowing from the power supply through the glow valve 145 encounters the low impedance of the rectifier 165 and the greater portion of the current flows therethrough rather than through the winding 142 of the transformer.

Inasmuch as the shunt path through the rectifying valve 165 presents a much lower impedance to the current from the power supply than does the winding 142 of the signal transformer 122, the action of the rectifier valve 165 in shunting the glow current therethrough effectively reduces the voltage to resistance ratio of the circuit through the glow valve. The rectifier 165 brings about this change in the condition of the glow valve 145; and it maintains the changed condition during the time that the valve 145 is glowing and so long as current flows through the rectifier 165 in the direction for taking power from the power supply.

The current passed by the power supply through the glow valve 145 and rectifying valve 165 also traverses the coil 146 of the relay 147 causing that relay to operate its contacts to effect the desired control function.

Subsequentl when the interrupter 150 opens its contacts, it completely interrupts all circuits through the glow valve 145 so as to terminate the glow operation thereof. When the interrupter 150 thereafter closes, the valve 145 does not resume its glow operation because the voltage impressed across it by the power supply is less than its ignition or striking voltage.

Thus, we have provided an electronic device shunting the signal input of the glow valve network, which device presents a high impedance to the voltage of the signal when the glow valve is not glowing and which responds to the glow operation of the valve to shunt effectively the high resistance of the signal input.

The system of Figure 3 constitutes the preferred embodiment of our present invention. The system of Figure 3 is superior to the systems of Figures 1 and 2 in that it is faster and more dependable in operation. The action of the valve 165 is electronic and it responds directly and immediately to the ignition of the glow valve 145. That is, it responds directly to the initiation of the glow operation of the valve 145. Consequently there is no appreciable delay or elapse of time between the ignition of the glow valve 145 and the boosting action of the rectifying valve 165. On the other hand, the actions of the relays of the systems of Figures 1 and 2, are in part mechanical and an appreciable delay occurs in each case between the initiation of the flow of

current resulting from the ignition of the glow valve **45** and the operation of the "booster" contacts of the relay. Each of the systems of Figures 1 and 2 is dependent upon its relay properly and successfully executing its initial operation on the weak initial glow current in order to accomplish the "boosting" of the current in the glow valve circuit, while the system of Figure 3 "boosts" the current regardless of the operation of its relay.

Figure 4 illustrates diagrammatically, and for the purpose of illustration, a modification of the glow valve circuit net of the system of Figure 3. Those parts of Figure 4 which have corresponding parts in the system of Figure 3 are indicated by the same reference numerals. The circuit net of Figure 4 consists of 3 branches as follows: The first branch includes a signal means or secondary winding **142** of the signal transformer **122**, and a battery or power supply **170**. The second branch includes the rectifying valve **165** and a battery or power supply **171**, and the third branch includes the glow valve **145**, the coil **146** of the relay **147**, the interrupter **150** and the battery or power supply **172**. The batteries **170**, **171**, and **172** are marked to indicate their polarities, and their polarities are such that in the closed circuit which includes the glow valve **145**, and the signal means **142**, the voltages of the batteries **170** and **172** therein add. This circuit is the ignition circuit of the glow valve **145**. Also, in the circuit through the glow valve **145**, and the rectifying valve **165**, the voltages of the batteries **171** and **172** therein add. This is the sustaining circuit of the glow valve **145**. The sum of the voltages of the batteries **170** and **172** must be less than the ignition voltage of the valve **145**, and the signal voltage appearing in the winding **142** of the transformer **122** must be of such value that when it is added to the voltages of the power supplies **170** and **172** it is sufficient to ignite the valve **145**. Also the sum of the voltages of the power supplies **171** and **172** must be in excess of the extinguishing voltage of the glow valve **145**. Generally it will be preferred to eliminate the two batteries **170** and **171**, in which case the circuit of Figure 4 reduces to the circuit of the system of Figure 3.

While we have shown and described certain specific embodiments of our invention, it will be apparent to those skilled in the art that the same are by way of illustration only and are capable of various modifications. Therefore, we do not wish to be limited except by the scope of the appended claims.

We claim:

1. In combination in a system of the class described, a glow valve having an anode and a cathode, an anode-cathode circuit therefore including said anode and cathode, a power supply in said circuit, and means other than said glow valve responsive to a flow of current from the anode to the cathode of said glow valve for increasing the current between said anode and cathode.

2. In combination in a system of the class described, a glow valve having an anode and a cathode, an anode-cathode circuit therefore including said anode and cathode, a power supply for applying voltage to said circuit, means for igniting said valve, a relay having a coil in said anode cathode circuit and means including contacts of said relay responsive to current in said anode cathode circuit for increasing the voltage applied to said circuit.

3. In combination in a system of the class described a glow valve having an anode and a cathode, an anode-cathode circuit therefor including said anode and cathode, a power supply in said circuit, a relay having a coil in said circuit, signal input means in said circuit for igniting said valve and contacts operated by said relay in response to the current which flows in said circuit when said valve is ignited for short circuiting said signal input means.

4. In combination in a system of the class described, an electronic amplifier, an impulse transformer having a primary winding connected to receive power from said amplifier, said transformer having, also, a secondary winding, and an electric glow valve having an anode and a cathode, an interrupter, a relay having a coil and normally open contacts, and a power supply having a voltage sufficient to sustain operation of said glow valve but insufficient to initiate a glow operation thereof, said secondary winding, glow valve, power supply, relay coil and interrupter being connected in series, said normally open contacts of said relay being included in a current path shunting said secondary winding.

5. In combination in a system of the class described, an electric glow valve having an anode and cathode, a direct current power supply having a voltage below the ignition voltage of said valve but above the extinguishing volt thereof, a high resistance signal means adapted to provide a signal voltage sufficient when added to the voltage of said power supply to ignite said valve, said power supply, the anode and cathode of said glow valve and said signal means being connected in series so that said voltages of said power supply and signal means add to ignite said valve, and means having an unsymmetrical impedance shunting said signal means for presenting a low impedance to current in the direction therethrough of said voltage of said power supply and for presenting a high impedance to currents therethrough in the direction of said signal voltage.

6. In combination in a system of the class described, an electric glow valve having an anode and a cathode, a direct current power supply having a voltage below the ignition voltage of said valve but above the extinguishing voltage thereof, a second valve which permits current to flow in only one direction therethrough, circuit connections providing a series circuit for the flow of current through said power supply in the direction of its voltage, through said second valve in the direction in which it passes current and through said glow valve from the anode to the cathode thereof, and signal means adapted to provide a voltage for igniting said glow valve and having two terminals, one of said terminals being connected to said series circuit at a first point between said second valve and said glow valve, the other of said terminals being connected at a second point of said series circuit which is between said glow valve and said second valve but on the opposite sides of both said valves from said first point.

7. In combination in a system of the class described, an electric glow valve having an anode and a cathode, a direct current power supply for supplying direct current at a voltage below the ignition voltage of said glow valve but above the extinguishing voltage thereof, said power supply comprising an alternating current supply, a rectifier and a filter, a high impedance signal means adapted to provide a voltage for igniting said valve, a relay, an interrupter and a second rectifier, the anode of said second rectifier being connected to the cathode of said glow valve and to one terminal of said signal means, said power

supply, relay and interrupter being connected in a series group between the anode the anode of said glow valve and the cathode of said rectifier, the other terminal of said signal means being connected to said series group.

8. In combination in a system of the class described, means for generating an impulse, an electronic amplifier for amplifying said impulse, a step up transformer having a primary winding for receiving the amplified impulse, said transformer, also, having a secondary winding, a glow valve connected to said secondary winding to receive the amplified and stepped up impulse therefrom, said valve being adapted to ignite upon receiving an impulse of sufficient voltage, a power supply connected to said glow valve for sustaining a glow operation of said valve when said valve ignites, a relay connected to said valve and responsive to a sustained glow operation of said valve, a rectifier shunting said secondary winding of said transformer so as to present its lower resistance to the current of said glow valve during a sustained glow operation thereof, and means for interrupting the circuit through said glow valve.

9. In combination in a system of the class described an electric glow valve having an anode and a cathode, a direct current power supply having a voltage below the ignition voltage of said valve but above the extinguishing voltage thereof, a high resistance signal means adapted to provide a signal voltage sufficient when added to the voltage of said power supply to ignite said glow valve, said direct current power supply, the anode and cathode of said glow valve and said signal means being connected in series in a series circuit so that said voltages of said power supply and said signal means add to ignite said valve, a shunt path connected between (1) a first point of said series circuit between said glow valve and said signal means and (2) a second point of said series circuit between said glow valve and signal means but on the opposite side of each said elements from said first point, and an electronic valve in said shunt path, said electronic valve in said shunt path being adapted to present a high impedance to the voltage of said signal when said glow valve is not glowing and to present a low impedance to the voltage of said direct current power supply when said glow valve is glowing.

10. In combination in a system of the class described, an electric glow valve having an anode and a cathode, a power supply having a voltage below the ignition voltage of said valve but above the extinguishing voltage thereof, a high impedance signal means adapted to provide a signal voltage sufficient when added to the voltage of said power supply to ignite said glow valve, said power supply, the anode and cathode of said glow valve and said signal means being connected in series in a series circuit so that said voltages of said power supply and said signal means add to ignite said valve, a shunt path connected between (1) a first point of said series circuit between said glow valve and said signal means and (2) a second point of said series circuit between said glow valve and signal means but on the opposite side of each said elements from said first point, and an electronic device in said shunt path adapted to present a high impedance to the voltage of said signal means when said glow valve is not glowing, said electronic device being responsive to a glow operation of said valve effectively to shunt the high impedance of said signal means.

11. In combination in a system of the class described an electric glow valve having a pair of electrodes, a power supply having a voltage below the ignition voltage of said glow valve but above the extinguishing voltage thereof, a second valve having electrodes and being adapted to conduct current only in one direction between its electrodes, circuit connections providing a series circuit for the flow of current through said power supply, through said second valve in the direction in which it passes current, and through said glow valve, and signal means adapted to provide a voltage for igniting said glow valve and having two terminals, one of said terminals being connected to an electrode of said glow valve and to an electrode of said second valve, the other of said terminals being connected to a point of said series circuit which is between said glow valve and said second valve but on opposite sides of both said valves from the connection to said first mentioned electrodes, said glow valve and said second valve connected to said first terminal of said signal means as aforesaid being so arranged as respects the polarities thereof that said valves and circuit connections therefor impose a minimum capacity shunt across said terminals of said signal means.

12. In combination in a system of the class described an electric glow valve having a pair of electrodes, a power supply having a voltage below the ignition voltage of said glow valve but above the extinguishing voltage thereof, a second valve having electrodes and being adapted to conduct current only in one direction between its electrodes, circuit connections providing a series circuit for the flow of current through said power supply, through said second valve in the direction in which it passes current, and through said glow valve, one of said valves having a cold cathode, the anode of the other of said valves being connected to said cold cathode, and signal means adapted to provide a voltage for igniting said glow valve and having two terminals, one of said terminals being connected to said cold cathode, the other of said terminals being connected to a point of said series circuit which is between said glow valve and said second valve but on opposite sides of both said valves from the connection of the first terminal to said cold cathode.

13. In combination in a system of the class described, an electric glow valve having an anode and a cold cathode, a direct current power supply having a voltage below the ignition voltage of said glow valve and above the extinguishing voltage thereof, said direct current power supply comprising a power transformer, a first rectifier and a filter, a second rectifying valve having an anode and a thermionic cathode, signal means adapted to provide a voltage for igniting said valve and having two terminals, an electric power supply including a winding of said power transformer for heating the thermionic cathode of said second rectifying valve, said cold cathode of said glow valve being connected to the anode of said second rectifying valve and to one terminal of said signal means, and circuit connections including said direct current power supply between the anode of said glow valve and the thermionic cathode of said second rectifying valve, said connections being so arranged as respects the polarity of said direct current power supply that the voltage of said direct current power supply

tends to pass a current through said glow valve from the anode to the cathode thereof, the other terminal of said signal means being connected to said circuit connections.

14. In combination in a system of the class described, an electric glow valve having an anode and a cathode, a power supply having a voltage below the ignition voltage of said glow valve but above the extinguishing voltage thereof, ignition means for igniting said valve, said power supply and ignition means being connected in an electric circuit with the anode and cathode of said glow valve, and means other than said glow valve, power supply and ignition means, responsive to a flow of current between the anode and cathode of said glow valve for increasing the current between said anode and cathode.

15. In combination in a system of the class described, an electric glow valve having an anode and a cathode, a power supply having a voltage insufficient to ignite said valve but sufficient to sustain a glow operation thereof, a high impedance signal means adapted to provide a signal voltage sufficient when added to the voltage of said power supply to ignite said valve, said power supply, the anode and cathode of said glow valve, and said signal means being connected in series so that said voltages add to ignite said glow valve, and means responsive to a glow operation of said glow valve for shunting the high impedance of said signal means.

16. The combination of claim 15, wherein said last means consists of an unsymmetrical impedance device whereby it presents a high shunt impedance to a signal but a low series impedance to the current drawn by said glow valve when glowing in response to said signal.

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