April 5, 1949. S. BREEN 2,466,634

ELECTRICAL APPARATUS

Filed Aug. 13, 1946 2 Sheets-Sheet 1

Fig. 1

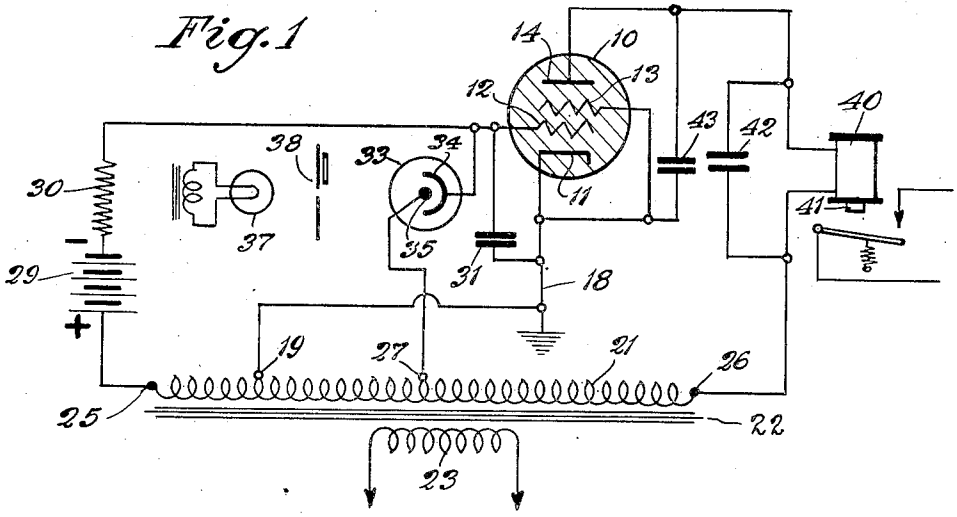
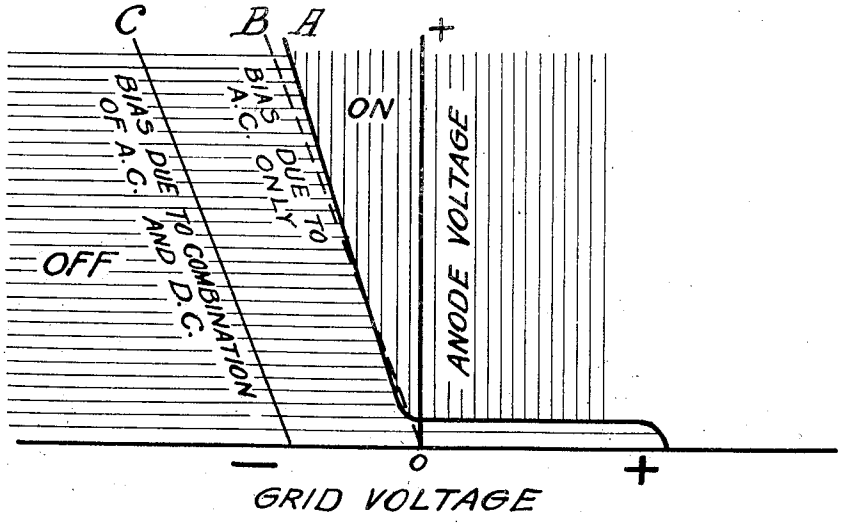


Fig. 2



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2 Sheets-Sheet 2

Fig. 3

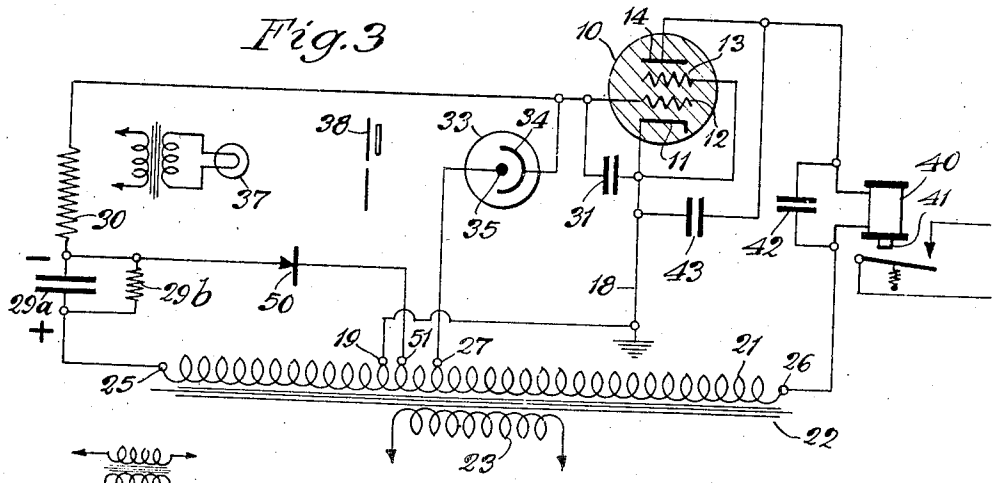


Fig. 4

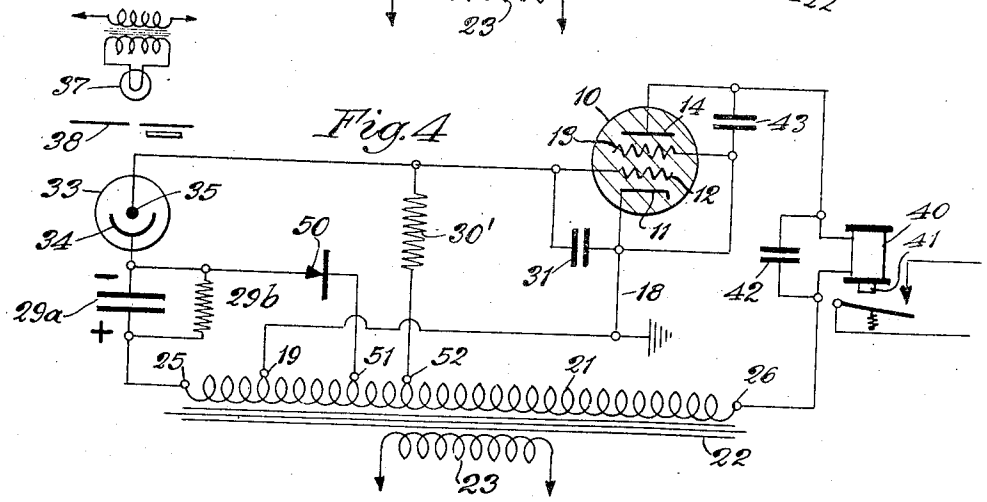
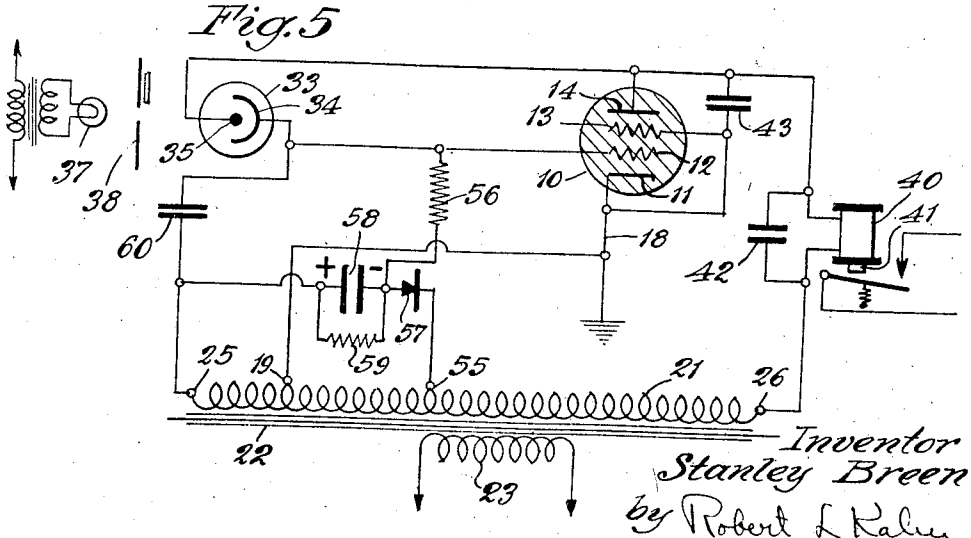


Fig. 5



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Patented Apr. 5, 1949

2,466,634

UNITED STATES PATENT OFFICE

2,466,634

ELECTRICAL APPARATUS

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Application August 13, 1946, Serial No. 690,294

19 Claims. (Cl. 250—41.5)

1

This invention relates to an electrical apparatus and particularly to a control system using a gaseous conduction electron discharge device having at least one control electrode. Grid-controlled glow discharge tubes are available in the market under various trade names, such as Thyratron for example, and are widely used. Such tubes, as is well known, comprise a gas-filled envelope in which are disposed cathode, control grid and anode electrodes with shield electrode in some instances. The cathode may be either of the hot or cold type. Such tubes are generally designated as grid-glow tubes and are adapted to function as a delicate relay.

Under normal operating conditions, a gaseous conduction device, after breakdown, is no longer subject to the action of a control electrode. It is understood, of course, that extreme potentials applied to such electrodes may function to extinguish a discharge. However, with normal circuits, the function of a control electrode disappears once a discharge has been initiated. In view of this characteristic, it is customary to energize the cathode-anode circuit of such devices with an alternating potential. Thus, the gaseous discharge is extinguished each half cycle on the reverse portion thereof. By virtue of this, the control electrode regains its control over the tube every half cycle.

In the grid-glow tubes generally available on the market, it is customary to have a conventional cathode and a heater therefor energized from some suitable source. As a rule, such tubes are energized by alternating current from one or more transformers with a filament or heater winding for energizing the heater or cathode, and a winding for impressing an alternating potential across the anode and cathode. The control grid is generally biased to some potential below firing, and reliance is had upon a supplemental trigger potential for firing the tube at a desired time. The actual firing potential on the control electrode of a grid-glow tube is related to the cathode to anode potential. In addition, the firing potential is a function of the tube characteristics and geometry and may vary from tube to tube due to manufacturing tolerances.

In systems using a grid-controlled gas tube having alternating potential impressed across the cathode and anode, it is customary to provide a variable bias potential, usually by means of a potentiometer for adjusting the bias of a control grid to a value suitable for the particular tube being used, the peak potential impressed at the anode, the possible variations in line voltage supplying the heater and anode circuits and the possible variations in trigger potential to be applied to the control electrode for firing the tube. Due to the large number of variables in one tube system, the variation in tubes due to manufacturing tolerances and the delicacy of control of the potential on the grid, it has hitherto been the practice to provide such a variable bias on the control electrode, which bias was adjusted by the user to suit individual requirements and conditions.

2

It is desirable from the user's point of view and from a manufacturing point of view to provide a system utilizing a grid-controlled gas tube in which adjustments are eliminated. This is particularly desirable from the user's point of view in that the user frequently lacks the technical ability to make a proper adjustment of the potentiometer. In addition, aging of a tube or system components and such variables as temperature and humidity may require a readjustment of the bias potential.

This invention provides a control system for a grid-glow tube wherein no adjustments of bias potential are required to compensate for varying tube characteristics, aging or variations due to temperature or humidity while maintaining the control system in a suitably delicate condition for triggering.

A system embodying the present invention is particularly adapted for use with such control elements as photoelectric cells or relays having a discontinuous resistance characteristic. Thus, a photoelectric cell may, under some conditions such as in total darkness, have a practically infinite resistance and change to a comparatively low resistance when brightly illuminated. The photoelectric cells having a gas-filling have an even greater resistance variation. In systems of the prior art using the combination of a photocell and a grid-glow tube all energized with alternating current, the requirements and limitations of bias on the control electrode has made it necessary to have a substantial potential variation at the photocell for triggering the control tube. This is particularly true if a stable system free from false triggering is to result. A control system including a grid-glow tube embodying the present invention is particularly adapted for use with a conventional photoelectric cell and requires a substantially lower potential variation across the cell terminals for providing light controlled triggering of the grid-glow tube. Instead of a photoelectric cell, a relay or any other source of trigger potential may be used.

The invention, in general, provides a control system wherein a grid-glow tube has alternating potentials impressed upon the anode-cathode circuit and has a fluctuating potential impressed upon the control grid. The fluctuating potential on the control grid is used for bias purposes and, in its simplest form, consists of an alternating potential mixed with a direct potential.

The relative values of direct and alternating potentials may vary over wide limits, subject, however, to the limitation that the instantaneous arithmetical sum of the two potentials constituting the instantaneous bias potential shall, throughout the positive part of the cycle in the cathode-anode circuit, have a fixed relation to the firing potential of the control electrode of the gas tube. Thus, if the normal condition of the gas tube is to be off, then the instantaneous bias potential of the control electrode should, throughout the positive portion of the cycle, be below the firing potential. Conversely, if the normal condition of the device is to be on, then the instantaneous bias potential of the control electrode during the positive portion of a cycle should be at least at the firing potential. While not essential, it is preferred to so proportion the alternating bias of the control electrode with respect to the cathode-anode potential that the grid potential curve is generally parallel to the linear part of the characteristic curve of the gas tube showing the firing potential of the control electrode as a function of the cathode-anode potential.

Superimposed upon the bias potential is an auxiliary source of potential which may vary in a manner to change the normal condition of the gas-discharge tube. Thus, an electron discharge device, as a photocell, may comprise part or all of the auxiliary potential source. The space current through such electron discharge device may be controlled in response to any desired condition. By energizing the cathode-anode circuit of the electron discharge device with alternating potential having a fixed phase relationship to the alternating potentials in the gas-discharge tube, a constant control relationship may be obtained.

In order to more fully describe the invention, reference will now be made to the drawings wherein Figure 1 is a circuit diagram of a system embodying the present invention. Figure 2 shows some characteristic curves of a gas discharge tube having a control electrode. Figure 3 shows the system of Figure 1 modified for complete energization from an alternating current source. Figure 4 shows a still further modification wherein the normal conditions of the system are different. Figure 5 shows a circuit diagram wherein the input circuit to the gas discharge tube is between the anode and control electrode.

Referring first to Figures 1 and 2, tube 10 having gas or vapor atmosphere has cathode 11, control grid 12, shield electrode 13 and anode 14. It is understood that cathode 11 may be provided with a heater. Cathode 11 is connected by grounded wire 18 to tap 19 on transformer winding 21 of power transformer 22. Transformer 22 has primary 23 energized from any suitable source of alternating current, such as the customary 110 volt, 60 cycle line. Winding 21 of transformer 22 has terminals 25 and 26 and an intermediate tap 27 in addition to tap 19. Terminal 25 is connected to the positive terminal of any suitable source of direct potential 29, this source being shown for simplicity as a battery. Source 29 has its negative terminal connected through resistance 30 to control grid 12 of tube 10. Grid 12 has by-pass condenser 31 connected to cathode 11, this condenser, in practice, serving to by-pass undesired disturbing potentials. Connected between control grid 12 and tap 27 is any suitable source of trigger potential, here shown as photoelectric cell 33. Cell 33 has cathode 34 connected directly to the control grid, while anode 35 of the cell is connected to junction 24. The cell itself may be biased if desired by any suitable auxiliary source of potential. Cell 33 may be of the high vacuum or gas type.

Cooperating with photo-cell 33 is light source 37 and shutter 38. The combination of photocell, light source and shutter is merely diagrammatic and may be varied within wide limits.

Anode 14 is connected to junction 24 through any suitable load, such as winding 40 of a relay 41. Winding 40 is preferably shunted by condenser 42, this condenser having a substantial capacitance of the order of several micro-farads. The condenser provides a filtering action and serves to maintain a constant load current. Condenser 43 between anode 14 and ground is provided for by-pass purposes.

It is understood that, in the system as shown, when light is flashed on cell 33, firing of tube 10 is to result. Since the photocell cathode is connected directly to control grid 12 of tube 10, it is evident that, when photocell 33 is illuminated, tube 10 will be fired. It is obvious that, by reversing the cell connections, the firing of tube 10 will be accomplished when the cell is dark. It is also possible to reverse potential source 29. Thus, tube 10 may be normally on or off as desired.

Referring now to Figure 2, some characteristic curves are shown illustrating the operating conditions of grid-glow tube 10. Thus, curve A is a general characteristic curve of a common type of grid-glow tube. As is well understood, the tube will remain blocked so long as the instantaneous grid potential remains in the region below and to the left of curve A.

Assuming now that some alternating potential is applied to the control electrode of the grid-glow tube and assuming that this potential always bears a fixed relation to the anode potential, such as for example as a ratio of one to ten, curve B may be drawn to show the bias due to the alternating potential. Curve B will intersect the zero axis at the origin and, at any instant, when the anode potential is positive, the corresponding alternating potential bias on the grid may be read off along a line parallel to the horizontal axis.

For all practical purposes, the most important part of curve A is the linear portion extending generally toward the origin. This curve, however, does not reach the origin and generally has a slope such that the projected portion of the linear part would intersect the horizontal axis near the origin.

It will be evident that, for prior art systems, line B must have such a slope that it does not intersect curve A at any point. In actual practice, line B will have to be tilted downwardly, thus providing a smaller or more gentle slope. Hence, in a system of the prior art, line B would start at the origin and diverge away from curve A with increasing anode potential. It follows, therefore, that at or near the peak of a positive half of a cycle, a substantial trigger potential would be necessary to overcome the grid bias at that particular instant. This trigger potential may be measured horizontally as the distance between

any point on line B and the corresponding point on curve A.

As shown here, however, line B has a slope which is generally the same as that of the linear portion of curve A. For a system of the prior art, line B, as drawn, would not be operative since it intersects curve A. However, in the practice of the invention, it is possible to adjust the alternating potential bias and thus the slope of line B to a value so that the line is as parallel to the linear portion of curve A as is reasonably possible.

The direct potential bias due to battery 29, with the polarity indicated, will shift line B left to give line C.

Line C shows the bias due to a combined alternating and direct potential. Obviously, the slope of lines B and C will be the same with the two lines being parallel and line C being displaced from line B by a distance corresponding to the fixed DC bias. It will be clear that, if line C is moved away from curve A so that the two do not intersect, no firing of the tube is possible without auxiliary potential. Thus, it is possible to adjust the DC bias so that line C is moved as close as desired to curve A.

The variation of tube characteristics due to aging of tube 10 or the changing of one tube for a new tube may result in some variation of curve A. The slope of line B will be fixed, since this is a circuit consideration independent of the tube characteristics. In practice, the extreme tolerancs of tubes available in the market and used as tube 10 in the circuit may be considered by a circuit designer. Thereafter, a suitable slope for line B may be selected, and a suitable direct potential bias may be selected to move line C clear of any characteristic curve A which may be encountered in commercial examples of tube 10. As a rule, the differences are not large so that line C may be brought fairly close to curve A.

It is evident from the above that the trigger potential for discharging the tube may be a relatively small and substantially constant potential over the greater part of the positive half of a cycle. During the negative portion of the cycle, no discharge is possible, and tube 10 merely functions as a high resistance.

Referring back to Figure 1, it will be noted that the potential impressed upon the photoelectric cell is fluctuating, consisting of an alternating potential and a direct potential component.

In the system illustrated in Figure 1, gas discharge tube 10 is normally off, this normal condition coinciding with normally dark photoelectric cell 33. With such a system, the alternating component on the photoelectric cell is in phase with the alternating potential upon the anode of gas discharge tube 10. If light conditions change so that the cell is illuminated, it will be evident that the output potential of the photoelectric cell will vary due to the alternating potential impressed across the cell. This output potential, which may be considered as a trigger potential, will thus have a linear relationship to the alternating potentials on the control electrode and anode of gas tube device 10. Thus, a high degree of control stability will be imparted to the system. The control exercised by the photoelectric cell will be substantially absolute over the entire positive portion of every cycle in the cathode-anode circuit of gas tube 10. This is in marked contrast to systems of the prior art wherein erratic performance was present. In such prior art systems, the potential at the photoelectric cell terminals might vary in operational effectiveness throughout the positive portion of a cycle on the gas tube electrodes. Thus, such prior art systems frequently failed to fire or to extinguish (depending upon which direction the control was exercised) because of unstable control characteristics.

Referring now to Figure 3, a modification is shown wherein direct current source 29 indicated as a battery in Figure 1 is replaced by a rectifier system, thus permitting the entire system to be operated from alternating current without the use of any batteries. Referring specifically to Figure 3, it will be noted that, instead of battery 29, condenser 29*a* shunted by resistor 29*b* are disposed between terminal 25 and resistor 30'. Rectifier 50 is connected between the lower terminal of resistor 30 and any suitable tap 51 on winding 21. The location of tap 51 and polarity of the rectifier may be varied to suit requirements.

It is evident that rectifier 50 will cause current to flow through resistor 29*b* in one direction only and charge condenser 29*a* to some denite potential. As a rule, depending upon the relation of the time constant of the charging circuit to the period of the alternating current supply line, the potential developed across condenser 29*a* will attain some fixed proportion of the peak potential present across terminals 51 and 25. As is well known in such circuits, it is preferred to have the time constant of the discharge circuit greater than the period of the alternating potential supplying the system. Thus, assuming a 60 cycle supply line, the time constant of the discharge circuit may be of the order of .1 second and even longer. When the system is first energized, condenser 29*a* will quickly become charged to a desired value after a number of cycles, and thus, a substantially direct potential bias will be provided. As shown here, the bias is such that the junction of resistor 30 and condenser 29*a* is negative with respect to terminal 25.

As one example of a system, the following components may be used. Tube 10 is type 2050, while cell 33 is type 927, the two type numbers being those manufactured by Radio Corporation of America and available on the market. Resistor 30 is five megohms. Battery 29 is four and one-half volts. Condenser 31 is .00003 micro-farad. Condenser 43 is .5 micro-farad. Condenser 42 is eight micro-farads. Winding 23 is energized with 110 volts, 60 cycles. The potential between junctions 19 and 25 is five volts, between junctions 25 and 27 fifty-four volts, and the potential between junctions 19 and 26 is 220 volts —all R. M. S.

For the circuit of Figure 3, condenser 29*a* has a capacitance of .5 micro-farad, while resistor 29*b* has a value of 200,000 ohms. Rectifier 50 is a selenium type available in the market for general use.

Load 40 has an iron core and has an impedance of 2500 ohms at 120 cycles.

In the two systems illustrated, a variation in potential across photocell 33 of the order of three or four volts is sufficient to trigger the grid-glow tube. With conventional circuits of the prior art, the same grid-glow tube having the same applied A. C. potentials would have required a change across the photocell terminals of the order of about twenty volts for triggering.

It is understood that the bias may be arranged so that line C is moved to the right so that tube 10 normally fires. In such case, the trigger

potential will have to be negative and bring the instantaneous grid bias to the "off" side of curve A. For such an arrangement, the D. C. bias would be reversed. It is also understood that the A. C. bias may be adjusted to provide any desired slope for line B. This, with a D. C. bias, may be relied upon for any desired control characteristics.

Referring now to Figure 4, there is shown a control system wherein gas discharge tube 10 fires on a decrease in light. In this circuit, photocell 33 is connected between control electrode 12 and the top terminal of condenser 29a. The anode of the cell is connected directly to the control electrode, the polarity thus being opposite to the circuit of Figure 3. Gride resistor 30' is connected between control electrode 12 and tap 52 on winding 21 to provide a suitable operating bias. It will be noted that the condenser charging circuit is substantially the same as in Figure 3.

In Figure 4, if cell 33 is dark (or has a suitably high resistance for a predetermined amount of light) the potential of control electrode 12 will be at or above firing value for a good part of the positive half of the cycle on the cathode and anode of tube 10.

Referring now to Figure 5, a circuit is shown of a control system wherein the trigger potential for firing or preventing from firing is applied between the control electrode and anode of the gas discharge tube. In this system, cell 33 has anode 35 connected to anode 14 of tube 10. Cathode 34 is connected to control electrode 12. Between control electrode 12 and the anode of rectifier 57 is grid resistor 56. Rectifier 57 and condenser 58 are connected in series between tap 55 and terminal 25. Resistor 59 is connected across condenser 58. The rectifier is poled as indicated. Phase shift condenser 60 is connected between terminal 25 and control electrode 12.

In this system, assuming cell 33 to be dark, control electrode 12 will be biased below firing potential. It is assumed, of course, that the position of tap 55 and the potential to which condenser 58 is charged will be properly adjusted. Upon conduction through cell 33, the potential of cathode 34 will be raised (upon positive halves of a cycle) to permit tube 10 to fire.

In all the systems described, the bias potential on the control electrode of the gas discharge tube has been due to the combination of a direct potential and alternating potential, the latter being always 180 degrees out of phase with the potential of the cathode and anode of the gas discharge tube.

Instead of a photoelectric cell, any other electron-discharge device may be used. In a cell, the amount of light falling on the cathode controls the space current. With other electron-discharge devices, other means as electromagnetic or electrostatic means may be used to control the space current through the device.

It is understood that a gas discharge device having cathode, anode and one or more auxiliary electrodes for control purposes may be analyzed in a manner analogous to a vacuum tube while the gas tube has no discharge therein. Thus, the control electrode and cathode may be considered as part of an input or control circuit, while the anode and cathode may be considered as part of an output or load circuit. The potential of any one or more of the electrodes of the gas tube must be defined with reference to some fixed point for reference purposes. It is customary in electron discharge devices, including both vacuum and gas tubes, to assume the cathode potential as a standard with reference to which the potentials of other electrodes are given. Thus, the potential of a control electrode in such a device will be assumed to be stated with reference to the cathode. The same applies to the potential of the anode.

Sometimes the potential of a control electrode is given with reference to the anode as a standard, particularly in gas tubes. Inasmuch as the anode potential itself is defined with reference to the cathode as a standard, it follows that giving the potential of a control electrode with reference to the anode is simply an indirect way of giving the potential of this same control electrode with reference to the cathode. Throughout the description and claims herein, the potential of control and anode electrodes of electron discharge devices is given with reference to the cathode. However, it is understood that any disposition of input circuit between the anode and control electrode and consequent use of the anode as a reference in considering the potential of a control electrode is fully equivalent and to be within the scope of the invention.

What is claimed is:

1. A control system comprising a gas discharge tube having cathode, control electrode and anode, means for impressing alternating potentials on said cathode and anode, means for impressing alternating potentials on said control electrode and cathode, said two potentials being in opposed relation, means for adding a substantially direct potential to the alternating potential on said control and cathode electrodes and an auxiliary source of potential connected between the control electrode and cathode, said auxiliary source being adapted to vary between two values for determining a firing or non-firing potential on said control electrode.

2. A control system comprising a gas discharge tube having cathode, anode and control electrodes, means for impressing a load circuit alternating potential upon said cathode and anode, means for impressing a biasing alternating potential on said control electrode and cathode, said biasing potential bearing a fixed relation to and being opposite in phase with the load circuit potential, means for adding to said alterating biasing potential a substantially constant biasing potential, said resultant biasing potential being sufficient to maintain said tube in a predetermined condition during positive portions of the cycles in said load circuit and means for impressing a trigger potential upon said control electrode and cathode, said trigger potential being adapted to assume a zero or fixed value in response to some condition to be controlled, said trigger potential having such a polarity and value as to cause a change in tube condition during positive portions of said cycles.

3. A control system comprising a gas discharge tube having cathode, control electrode and anode, means for impressing a first alternating potential across the cathode and anode electrodes, means for impressing a second alternating potential on the control and cathode electrodes, said second potential being opposite in phase and less than said first potential, means for adding a substantially direct potential to said second potential to provide a resultant bias potential and means for intermittently applying an alternating trigger potential to said control and cathode electrodes in response to predetermined conditions, said resultant bias potential being sufficient to

maintain said tube in a predetermined discharge condition during positive portions of the cathode-anode cycle and said intermittent trigger potential having sufficient magnitude and polarity so that upon a change of conditions in the trigger circuit said tube conditions change.

4. A control system comprising a gas discharge tube having cathode, anode and control electrodes, means for applying an alternating potential to the anode and cathode, means for supplying an alternating bias potential to the control electrode and cathode, said bias potential being less than and having its phase opposed to said first-named potential, means for adding a substantially constant bias potential to said alternating bias potential to provide a resultant potential, said constant bias potential being so poled as to bias said control electrode negative with respect to said cathode during positive parts of cycles of the first-named potential, and means connected between said control electrode and cathode for applying an alternating trigger potential in response to a condition to be controlled, said trigger potential when applied being in phase with the cathode-anode potential, said resultant bias potential being sufficient to prevent firing of said tube and said trigger potential being sufficient to cause firing of said tube during positive parts of cycles.

5. A control system comprising a gas discharge tube having cathode and anode electrodes in an output circuit and control and cathode electrodes in an input circuit, means for supplying alternating potential in said output circuit, means for supplying an alternating bias potential in said input circuit, said alternating bias potential being less than and having a phase opposite to the potential across said cathode and anode, means for adding to said alternating bias potential a substantially direct bias potential to form a resultant bias potential, said resultant bias potential maintaining said control electrode below the firing point and means for applying an alternating trigger potential upon said control and cathode electrodes in response to some conditions, said trigger potential being in phase with the output potential and being sufficient to cause firing.

6. The system of claim 5 wherein said alternating bias potential bears such a relation to the potention across the anode and cathode that a curve showing control electrode potential against anode potential is substantially parallel to the linear portion of the characteristic curve of said tube showing the threshold firing potential of said control electrode plotted against anode potential.

7. A control system comprising a gas discharge tube having cathode and anode electrodes in an output circuit and control and cathode electrodes in an input circuit, means for supplying alternating potential in said output circuit, means for supplying an alternating bias potential in said input circuit, said alternating bias potential being less than and having a phase opposite to the potential across said cathode and anode, means including a resistance-condenser combination in said input circuit for adding a substantially direct bias potential, said direct and alternating potentials in said input circuit forming a resultant bias potential, said resultant bias potential maintaining said control electrode potential upon one side of the threshold firing potential during positive portions of the cycles at the cathode and anode, and means for supplying a trigger potential upon said control and cathode electrodes, said trigger potential having a predetermined R. M. S. value or zero R. M. S. value, said trigger potential being adapted to vary the potential of said control electrode during positive portions of a cycle to the other side of the firing potential to cause a change in tube condition.

8. A control system comprising a gas discharge tube having cathode and anode electrodes in an output circuit and control and cathode electrodes in an input circuit, means for supplying an alternating bias potential in said input circuit, said alternating bias potential being less than and having a phase opposite to the potential across said cathode and anode, a condenser connected in the input circuit, a charging circuit for maintaining a substantially constant potential across said condenser, said constant potential being added to said alternating bias potential to provide a resultant bias potential on said control electrode, and means for applying a trigger potential on said input circuit, said resultant bias potential having such a magnitude as to maintain said tube in a predetermined condition during positive portions of the cathode-anode potential cycle and said trigger potential being sufficient to change the tube condition.

9. The system of claim 8 wherein said means for applying a trigger potential comprises a photoelectric cell and means for applying an alternating potential to said cell, said alternating potential being in phase with the alternating potential in the output circuit of the gas discharge tube.

10. The system of claim 8 wherein said means for maintaining said condenser charged include a rectifier and resistor.

11. The system of claim 8 wherein the potential impressed upon said condenser has such a polarity that the negative terminal of said condenser is on the control electrode side of the system.

12. In a control system having a grid controlled gas discharge tube with alternating potential impressed upon the anode and cathode, the method of operating said tube which comprises biasing the control electrode with a fluctuating potential consisting of mixed direct and alternating potentials to provide a resultant bias potential to maintain the tube in a predetermined condition during positive portions of the cathode-anode cycle and varying said resultant bias potential in response to a condition to be controlled for changing the tube condition.

13. In a control system having a grid controlled gas discharge tube with alternating potential impressed upon the anode and cathode, the method of operating said tube which comprises biasing the control electrode with a fluctuating resultant potential consisting of a direct and alternating potential, said alternating potential being opposite in phase to the cathode-anode potential and having a value substantially less than said cathode-anode potential, said alternating bias potential being sufficient to define a line showing control electrode potential plotted against anode potential substantially parallel to the linear portion of the characteristic curve of the tube showing threshold firing potential of the control electrode plotted against anode potential.

14. A control system comprising a gas discharge tube having cathode, control electrode and anode, means for impressing alternating potentials on said cathode and anode, means for impressing alternating potentials on said control electrode and cathode, said two potentials being in opposed relation, means for adding a substan-

tially direct potential to the alternating potential on said control and cathode electrodes, an electron discharge device having at least a cathode and anode, means for connecting said electron discharge device in said grid circuit of said gas discharge tube, means for controlling the space current in said electron discharge device, said direct and alternating potential on the control electrode of said gas discharge tube having such an instantaneous value during positive portions of the cycle in the cathode-anode circuit of said tube as to prevent firing of the tube and said electron discharge device being adapted when its space current is properly controlled to change the potential of said control electrode of said gas tube to a firing value.

15. The system of claim 14 wherein said electron discharge device is a photoelectric cell.

16. The system of claim 14 wherein the means for adding the direct potential includes a condenser and charging circuit.

17. The system of claim 14 wherein the means for adding the direct potential includes a condenser, resistor and rectifier.

18. A control system comprising a gas discharge tube having cathode, control grid, and anode, a transformer winding for supplying alternating potentials to said system, a load for said cathode-anode circuit, connections for disposing said load between one terminal of said winding and said anode, a source of direct potential and a resistor connected in series between the other terminal of said winding and control grid, a connection between said cathode and one tap on said winding, said one tap being between

the center and other terminal of said winding, a photoelectric cell having cathode and anode, a connection between the cell cathode and control grid, a connection between the cell anode and another tap on said winding, said cell being adapted to fire the tube upon an increase in light.

19. A control system comprising a gas discharge tube having cathode, control grid and anode, a transformer winding for supplying alternating potentials to said system, a load for said cathode and anode circuit, connections for disposing said load between one terminal of said winding and said anode, a photoelectric cell having cathode and anode, means for connecting said cell anode to said control grid, a source of constant potential, means for connecting said source of potential between said cell cathode and other winding terminal of the connection between the tube cathode and one winding tap, said one tap being between said other terminal and center of the winding, said tube being adapted to fire when said cell has a minimum of light and to block upon an increase of light on said cell.

STANLEY BREEN.

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The following references are of record in the file of this patent:

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Disclaimer

2,466,634.—*Stanley Breen*, Elgin, Ill. ELECTRICAL APPARATUS. Patent dated Apr. 5, 1949. Disclaimer filed Apr. 19, 1949, by the inventor and the assignee, *Operadio Manufacturing Co.*

Hereby enter this disclaimer to claim 12 in said specification.

[*Official Gazette June 7, 1949.*]

Disclaimer

2,466,634.—*Stanley Breen*, Elgin, Ill. ELECTRICAL APPARATUS. Patent dated Apr. 5, 1949. Disclaimer filed Apr. 19, 1949, by the inventor and the assignee, *Operadio Manufacturing Co.*

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[*Official Gazette June 7, 1949.*]