

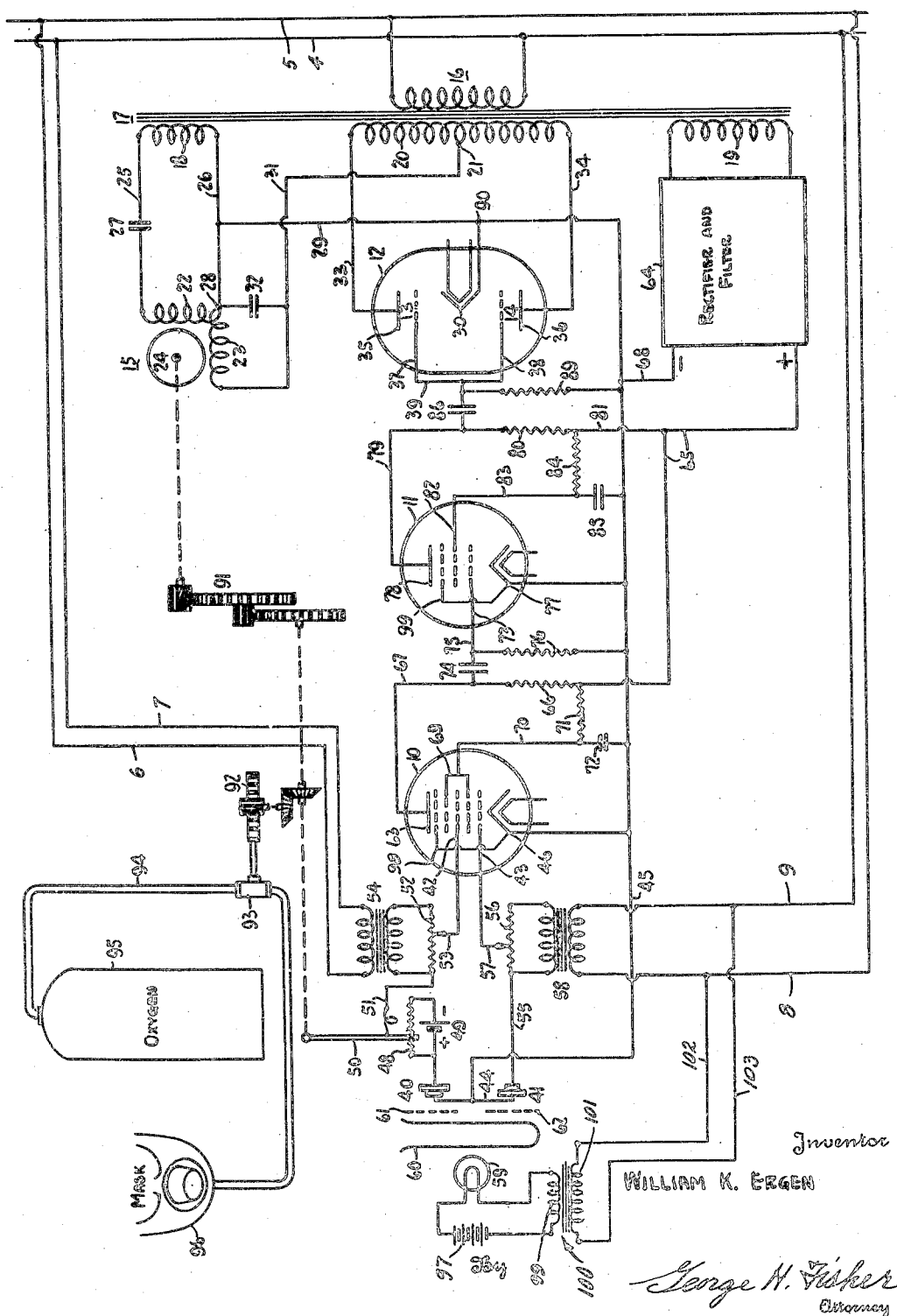
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ELECTRONIC MOTOR CONTROL APPARATUS

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ELECTRONIC MOTOR CONTROL APPARATUS

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This invention relates generally to improvements in control methods and means of an electrical nature and more especially to an electronic system wherein an indicator, motor or other working unit is controlled and actuated in accordance with the ratio or difference between two signals, or other control factors.

The primary object of the invention is to provide an apparatus, or system, and method, of this nature which may be used for automatically controlling the rate of oxygen supply to an aviator in accordance with his requirements. The amount of oxygen required by an aviator flying at high altitudes varies, of course, and requires more or less adjustment as the altitude varies during flight. Such adjustment has heretofore, to my knowledge, been usually made manually and is unsatisfactory in that the aviator, on the one hand, may so adjust the oxygen controlling valve that he is supplied with more oxygen than actually required, thus resulting in a waste, or on the other hand and more important, he may not realize his need for additional oxygen in time to properly adjust the valve, with possibly disastrous results.

I accomplish this result primarily by employing the varying absorption of the aviator's blood for red and green light, the ratio of such absorption being, as well known in the spectrophotometric field, a direct function of the oxygen saturation of the blood. The red light is of a wavelength such that it is absorbed essentially only by the reduced hemoglobin, or hemoglobin carrying little if any oxygen, whereas the wavelength of the green light is such that it is absorbed by the oxygen saturated, as well as the reduced hemoglobin, or in other words by the hemoglobin as a whole.

The ear lobe offers probably the best point for the projection of these light rays through the blood and tissue, and the light intensity, after passing through the lobe may be expressed by the following formulae:

For the red light (L_r)—

$$(1) \quad L_r = A_r e^{-D_r c}$$

where A_r involves such factors as the intensity of the light source, absorption in the tissues of the ear lobe and similar factors; D_r involves the amount of blood in the path of the light beam and the specific absorption for red light of the reduced hemoglobin; and c is the fraction of reduced hemoglobin present.

And for green light (L_g)—

$$(2) \quad L_g = A_g e^{-D_g c}$$

where L_g , A , and D are all of the same mean-

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ing as L_r , A_r , and D_r , respectively, only measured with green light.

The fraction " c " of reduced hemoglobin is seen to be usable by proper adjustments herein to be described, not only to indicate the requirements for the administration of oxygen but also ultimately to control the oxygen supply.

In accordance with my object, a periodically varying light beam passing through the blood is impressed upon separate photovoltaic cells covered with red and green filters respectively thereby to be responsive to red and green light respectively. Such cells will generate alternating signal voltages whose relative magnitude is dependent upon the value of the fraction " c " of reduced hemoglobin. The photovoltaic cells are connected to the input circuits of a pentagrid converter or mixer tube forming the first stage of an electronic amplifier. The input impedances of this multi-grid tube are sufficiently high with respect to the resistances of the cells and the light intensities have such values that the voltage developed by each cell is a linear function of the logarithm of the light intensity. Thus, the input voltages can be determined by considering the logarithms of the above expressions for L_r and L_g . In other words, if the alternating voltage caused by the light intensity L_r is expressed by the term e_r and the alternating voltage produced by the light intensity L_g by e_g , the following equations result:

$$(3) \quad e_r = A_r - D_r c$$

$$(4) \quad e_g = A_g - D_g c$$

where A_r involves the logarithm of A_r and certain characteristics of the photocell. The term A_g is analogous. The terms D_r and D_g are proportional to D_r and D_g .

Means are provided to cancel out the terms A_r and A_g . Then the input e_r will cause an amplifier output

$$(5) \quad O_r = g_r D_r c$$

Similarly the input voltage e_g causes an output

$$(6) \quad O_g = g_g D_g c$$

In formulas (5) and (6) g_r and g_g are the amplifier gains. If the amplifier gains are properly adjusted, O_r can be made equal to O_g so that if the voltages are opposed to each other, the resulting voltage is equal to zero. In other words, under these conditions,

$$(7) \quad O_r - O_g = 0$$

This is equivalent to

$$(8) \quad \frac{g_r}{g_g} = \frac{D_r}{D_g}$$

Thus, any magnitude connected with the ampli-

fler gains will be indicative of the concentration of reduced hemoglobin and thus of the oxygen saturation of the blood. This magnitude will not change when the total amount of blood changes since this would mean that d_r and d_g are multiplied by the same factor.

In my apparatus, the alternating output of the tube to which both photovoltaic cells are connected is amplified and fed to further stages as required, but is finally employed to actuate a servomotor controlling the oxygen supply unit. The photovoltaic cells are so connected to the grids of the first multi-grid tube that the alternating voltage signals impressed on these grids are of opposite time phase. Means are provided to cancel the factors corresponding to the terms a_r and a_g in Equations (3) and (4), and to adjust the ratio between the gains g_r and g_g . The apparatus is so adjusted that the effects of the two alternating voltage signals are cancelled out when a certain normal oxygen saturation of the blood exists. When this ratio changes, due to either an increase or decrease of the oxygen content of the blood, the alternating voltages developed by the photovoltaic cells as a result of the variation in light absorption of the blood under these conditions, will be reflected by the appearance of an alternating potential in the amplifier, the time phase of which depends upon whether the reduced hemoglobin content of blood has increased or decreased. This phase relation determines the direction of rotation of the servomotor which then adjusts the oxygen valve accordingly.

The ratio between the two signals as they appear at the grids of the pentagrid tube is thus seen to control the output of the tube and the operation of the elements connected thereto, and it is another and important object of my invention, therefore, to provide an apparatus and method for controlling the operation of a motor, indicator, or other working element, in response to this ratio between two signals or factors, when such factors are applied to a mixer tube at separate grids thereof. The application of different signals to the control and oscillator grids of a mixer tube is known in the art, but heretofore such signals have been of different or beating frequencies, whereas in my invention the signals are of opposite time phase, but of the same frequency, so that they may be bucked out at a selected ratio between their magnitudes and so that subsequent variations in their ratio will achieve the desired results.

Still another object is to provide an amplifier circuit of this nature in a simple and effective form and embodying simple means for bucking out the energizing signals at certain levels, and compensating for minor variations in the connected circuit elements, biasing means for establishing the required equilibrium in the circuit at the selected signal ratio, and motor controlled means for varying this bias for reestablishing this equilibrium as the signal ratio varies.

Other objects and advantages of the invention will be made apparent in the course of the following specification, taken in connection with the accompanying drawing.

The drawing represents a circuit diagram embodying my invention, showing the same in its application to the control of the oxygen supply for an aviator, parts of the oxygen system being shown diagrammatically.

My circuit is seen to comprise, in the exemplification herein shown, a three stage electronic

amplifier having a pentagrid converter or mixer tube 10 as its first stage, a pentode tube 11 as its second stage and a final amplifier of the twin triode variety, designated at 12, having the triodes 13 and 14. The final stage supplies power intermittently to one phase of a reversible split phase motor 15, the other phase of which is continuously supplied from an alternating current source.

The system as a whole is supplied with power from line wires 4 and 5 which lead to any suitable source of alternating current (not shown). A primary 16 of a transformer 17 is connected to line wires 4 and 5. The transformer 17 has a number of secondary windings 18, 19 and 20. Winding 18 supplies power to one phase of motor 15, winding 19 supplies power to the preliminary stages of the amplifier through a conventional rectifier and filter system, and winding 20 supplies an alternating anode voltage for the twin triode final amplifier 12, this winding being center tapped as indicated at 21.

The motor 15 has field windings 22 and 23 and a rotor 24, and the motor is, as stated, of the split phase type wherein the field windings are displaced in space phase and wherein the difference in time phase of the currents flowing in the windings determines the direction of rotation of rotor 20. The field winding 22 is provided with an alternating potential of a certain phase from transformer winding 18 through circuit conductors 25 and 26 with a condenser 27 interposed in the conductor 25. The conductor 25, connected with the common terminal 28 of the motor windings, is also connected by conductor 29 to the cathode 30 of the final amplifier tube 12.

The condenser 27 forms, with field winding 22, approximately a series resonant circuit the characteristics of which causes the current flowing in winding 22 to be in time phase with reference to the terminal voltage of transformer winding 18, and due to the inductance in the winding the voltage across the field winding leads the terminal voltage of the transformer by approximately ninety electrical degrees.

The field winding 23 receives current chiefly (some being supplied by induction from winding 22 when the motor is running) from the output of the final amplifier tube 12 through common conductor 29 and terminal 28 and through a conductor 31 leading to the center tap 21 of transformer winding 20. A condenser 32 is connected across the field winding 23 and the purpose of this condenser is primarily to suppress harmonics and to bring the voltage across winding 23 in the proper phase relation to the voltage across winding 22. Conductors 33 and 34 connect the respective ends of the transformer winding 20 to the anodes 35 and 36 of the twin triodes 13 and 14, completing this part of the circuit, it being understood of course that the circuit from anodes to cathode 30 is completed through center tap 21, conductor 31, field winding 23, terminal 28 and conductor 29 as may be readily traced.

The control grids 37 and 38 of the triodes are tied or brought together as represented at 39. Now as the transformer winding supplies the alternating anode voltage to this tube the result, without excitation at the grids, will be little alternating current flow in the field winding 23 since the alternating voltage on the respective anodes 35 and 36 is of opposite time phase. No motor rotation will occur under such conditions. If, however, a voltage signal is applied to the grids which is in-phase with the alternating anode po-

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tential on one of the triodes, then a voltage will be developed at that phase in the motor field winding 23. Since the voltage across the other field winding 22 is, as heretofore stated, ninety electrical degrees out of phase with the terminal voltage of the transformer, then necessarily it will either lead or lag the current in winding 23 by this amount causing motor rotation. The direction of such rotation will depend on the phase relation of the exciting signal potential to that of the voltages applied to the anode circuits of the respective triodes 13 and 14, as should be readily understood.

This type of amplifier and servo-motor system is analyzed and described in greater detail in the copending application of Albert P. Upton, Serial No. 437,561 filed April 3, 1942, now matured into Patent No. 2,423,534 issued July 8, 1947, assigned to the assignee of this application.

This final amplifier-motor circuit is driven by the preliminary amplifier made up of the tubes 10 and 11 now to be described, and which preliminary amplifier is herein shown as energized from two photovoltaic cells 40-41 so connected as to supply alternating signal voltages approximately one hundred eighty electrical degrees out of phase but of the same frequency to the control grid 42 and oscillator grid 43, respectively, of the pentagrid converter tube 10. The conductor 44 connecting the cells leads to the common conductor or negative lead 45 to which the cathode 46 of tube 10 is also connected. The circuit from photovoltaic cell 40 to control grid 42 includes a potentiometer 48, across which appears a direct current bias here shown as derived from a battery 49. One terminal of the potentiometer 48 is connected to photovoltaic cell 40 while the slider 50 is connected, as indicated at 51, to one terminal of a second potentiometer 52, the slider 53 of which then is connected to the grid. Connected across the potentiometer 52 is a source of an alternating bucking potential which is shown, for convenience sake, as a transformer 54. The circuit from photovoltaic cell 41 to the oscillator grid 43 is formed by a conductor 55 connected between the cell and one terminal of a third potentiometer 56, the slider 57 of which then is connected to the grid. A transformer 58 is here again indicated as connected with its output across the potentiometer 56 to supply an alternating bucking voltage. The primary windings of transformers 54 and 58 are connected through conductors 6, 7, 8, and 9 to line wires 4 and 5.

A lamp 59 supplied from a suitable alternating current source is arranged to direct a beam of light upon the photovoltaic cells 40 and 41 through the ear lobe indicated at 60, and through red and green filters 61 and 62 with which the cells are respectively covered. The cells are thus affected only by light of red and green wavelengths, respectively forming part of the spectrum of the beam from lamp 59. Either the alternating current source to which the lamp 59 is connected should be of half the frequency of the source to which the primary winding 16 and transformers 54 and 58 are connected or a suitable constant source of voltage should be connected to the lamp 59 in series with the alternating source so that at no time is the lamp completely extinguished. The latter method is preferable in insuring a constant phase relationship between the lamp energizing voltage and the voltage supplied to winding 22 of motor 15. In the drawing the lamp is shown as connected in series with a battery 97 to the secondary 99 of a trans-

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former 100. Primary winding 101 of transformer 100 is connected by conductors 102 and 8, 9, and 103 to line wires 4 and 5. When the lamp 59 is energized in this manner, the effect of the light on the photovoltaic cells is to cause them to generate alternating voltages of the same frequency as that of the source to which primary winding 16 is connected.

The anode 63 of tube 10 is supplied with a direct current potential by the rectifier and filter unit 64 which is itself supplied from the transformer winding 19, this circuit including the conductor 65, load resistor 66 and anode lead 67. A conductor 68 from the unit 64 to the common lead 45 completes the circuit from anode to cathode as will be apparent. The screen grid structure 69 of the tube 10 is connected by a lead 70 and resistor 71 to the direct current source 64 and is connected through condenser 72 to cathode so that the screen is maintained at the same alternating current potential as the cathode. The suppressor grid 98 is connected in the conventional manner to the cathode 46.

The output of tube 10 is led to the control grid 73 of the pentode tube 11 through a blocking and coupling condenser 74 connected to the anode conductor 67 and leading through conductor 75 to the grid 73. The circuit from the grid 73 to cathode 77 includes a resistor 76 connected from the grid to the common or negative lead 45. The anode 78 of tube 11 is connected through conductor 79, plate load resistor 80 and conductor 81 to the conductor 65 carrying the direct current potential while the screen grid 82 of the tube is connected through lead 83 and dropping resistor 84 to the same supply. This screen grid is held at the same alternating potential as the cathode by the conventionally arranged bypass condenser 85. The suppressor grid 99 is connected, as normal, to cathode 77.

The output circuit of tube 11 is coupled through a blocking condenser 86 to the common connection 39 of the grids of the final amplifier tube 12 while the input circuit for this tube is completed by means of a resistor 89 leading to the cathode 30 through the common lead 45, to which the cathode is connected as shown at 90.

Obviously, one or more additional stages of amplification might be embodied between the first and final stages of the circuit where the amplitude of the signals being handled requires greater amplification.

The motor is shown as having its rotor 24 connected through a gear train 91 with the slider 50 of the bias adjusting potentiometer 48 and also, as one example of its use, the motor is shown as connected through a pinion and rack mechanism 92 with a valve 93 so that the valve will be opened and closed, according to the direction of motor rotation. The valve 93 is arranged in the line 94 between the oxygen supply tank 95 and the oxygen mask 96, to control the flow of oxygen to the latter.

In operation, the alternating signal voltages developed by the photovoltaic cells 40 and 41 which are approximately one hundred eighty electrical degrees out of phase, are impressed, respectively, on the control and oscillator grids 42 and 43 of the pentagrid tube 10, causing an alternating potential in the output circuit of that tube. The time phase relation of this output alternating voltage depends on the ratio between the input signals, and is amplified by the pentode tube 11 and appears at the grids 37-38 of the final

amplifier tube 12 where it causes the rotation of the motor 15 in a direction dependent on the phase of the signal of greater or increased magnitude. The rotation of motor 15 adjusts the slider 50 of the potentiometer 48 which varies the effective D. C. bias on the control grid 42 of the pentagrid tube. The amount of D. C. bias that is applied to grid 42 determines the portion of the tube characteristic curve over which the tube will operate and hence the effect that a given variation in the voltage applied to grid 42 will have on the output current of the tube. In other words, this bias determines the gain corresponding to the term g_r in Equation (5). At a certain value of this bias, the control grid alternating signal voltage obviously will have exactly the same amount of influence upon the anode current of the tube as does the alternating signal voltage at the oscillator grid 43, and the two influences will substantially balance out each other so that no alternating current will flow in the output circuit of the tube. When this condition is reached there will, of course, be no current flowing in the field winding 23 of the motor and the motor will not rotate. A condition of equilibrium will thus be established in the circuit. However, if the ratio between the alternating signal voltages at the grids 42 and 43 is varied, the bias thus established by the potentiometer 48 will be either too high or too low, depending on which signal increases in magnitude, and this equilibrium will be destroyed so that one grid will have more influence than the other and an alternating potential will appear in the anode circuit. The phase of this signal voltage will depend directly on the phase of the signal increasing in magnitude and the motor 15 will rotate in the proper direction to again regulate the bias to the new ratio between signals, reestablishing the equilibrium. Such equilibrium will not be affected except by a change in the ratio of the magnitude of the signals applied to the grids 42 and 43, the increase in both signals by the same factor not having any effect since the ratio remains constant in such case.

Since, as has been described, the absorption of the red and green light rays by the blood is at a ratio which is a direct function of the oxygen content of the blood, the signal voltages generated by the photovoltaic cells 40 and 41 will vary strictly in accordance with the changes in such light absorption. The resulting alternating voltages applied to the grids of the tube 10, being opposite in phase and varying in ratio as the blood condition changes, the motor 15 will be rotated in the proper direction to adjust the valve 93 and open or close the same as required to adjust the rate of oxygen flow to the mask 96 according to requirements. At the same time the potentiometer 48 is adjusted to bring the circuit to a new equilibrium causing the motor to stop and the valve to remain in the position to which it has been moved until the oxygen saturation of the blood returns to normal. There results, of course, a more or less constant adjustment of the valve in accordance with the changing requirements for oxygen and without any attention whatever on the part of the aviator.

The alternating potentials supplied to the grids 42 and 43 by the transformers 54 and 58, and controlled by the potentiometers 52 and 56, are required in order to cancel out components of the signals which are more or less constant and which if not canceled out would prevent the input voltages being directly related to the fraction of total hemoglobin which is in the reduced state. In

other words, these alternating potentials are employed to cancel out the factor corresponding to terms a_r and a_g in Equations (3) and (4).

Primarily, my invention is seen to comprise a method and means for electronically regulating or measuring the difference between two signals of opposite time phase but of the same frequency, or utilizing the changing ratio between such signals to control a pentagrid tube and provide actuating voltages as such ratio varies. Obviously, therefore, the invention will find uses other than that herein specifically set forth, such as for measuring purposes, for indicating the ratio between two factors or magnitudes, and the direction in which such ratio may vary, or as a control for a motor or suitable relays for doing work of various kinds.

Having now fully described my invention, what I claim as new and desire to secure by Letters Patent is:

1. An apparatus for controlling a motor of the type responsive to energization by alternating currents of opposite time phase which control its direction of rotation, comprising the combination of an electronic amplifier including a pentagrid mixer tube having its control and oscillator grids excited by alternating control signals of variable amplitudes and opposite time phase, means whereby changes in the ratio between the amplitudes of the respective signals appearing at the grids will be reflected by alternating currents in the output of the amplifier of time phase relation to the signals, means for bucking out variable factors in the signals appearing at the grids, and the said output of the amplifier being connected to supply said alternating currents to the motor.

2. In combination, an electron discharge device having an anode and a cathode connected in an output circuit of said discharge device and a pair of control electrodes associated with said anode and cathode and both controlling the current flow between said cathode and anode, each control electrode being connected into a different input circuit of said discharge device, means for continually supplying to said input circuits alternating voltages relatively variable in magnitude and opposite in phase, means for applying a bias to one of said control electrodes to cause the control electrodes to have an equal but opposite effect upon the anode current at a predetermined ratio of said alternating voltage, an alternating current energized motor to be controlled in accordance with the relative values of said alternating voltages, and means associated with said output circuit for controlling the energization of said motor in accordance with the relative opposing effects of the voltages applied to said input circuits.

3. In combination, an electron discharge device having an anode and a cathode connected in an output circuit of said discharge device and a pair of control electrodes associated with said anode and cathode and both controlling the current flow between said cathode and anode, each control electrode being connected into a different input circuit of said discharge device, means for continually supplying to each of said input circuits alternating voltages relatively variable in magnitude and opposite in phase, means for applying a bias to one of said control electrodes to cause the control electrodes to have an equal but opposite effect upon the anode current at a predetermined ratio of said alternating voltages, an alternating current energized motor to be con-

trolled in accordance with the relative values of said alternating voltages, means associated with said output circuit for controlling the energization of said motor in accordance with the relative opposing effects of the voltages applied to said input circuits, and means positioned by said motor for adjusting said biasing means until the effect of the electrodes is equal.

4. In combination, an electron discharge device having an anode and a cathode connected in an output circuit of said discharge device and a pair of control electrodes associated with said anode and cathode and both controlling the current flow between said cathode and anode, each control electrode being connected into a different input circuit of said discharge device, means for continually supplying to said input circuits alternating voltages relatively variable in magnitude and opposite in phase, means associated with each input circuit for automatically varying the magnitude and phase of the alternating voltage supplied to the input circuit in accordance with the value of a physical condition, means for applying a bias to one of said control electrodes to cause the control electrodes to have an equal but opposite effect upon the anode current at a predetermined ratio of said alternating voltages, an electric motor to be controlled in accordance with the relative values of said alternating voltages, and means associated with said output circuit for controlling the energization of said motor in accordance with the relative opposing effects of the voltages applied to said input circuits.

5. In combination, an electron discharge device having an anode and a cathode connected in an output circuit of said discharge device and a pair of control electrodes associated with said anode and cathode and both controlling the current flow between said cathode and anode, each control electrode being connected into a

different input circuit of said discharge device, means for continually supplying to each of said input circuits alternating voltages relatively variable in magnitude and opposite in phase, means associated with each input circuit for automatically varying the magnitude and phase of the alternating voltage supplied to the input circuit in accordance with the value of a physical condition, means for applying a bias to one of said control electrodes to cause the control electrodes to have an equal but opposite effect upon the anode current at a predetermined ratio of said alternating voltages, an electric motor to be controlled in accordance with the relative values of said alternating voltages, means associated with said output circuit for controlling the energization of said motor in accordance with the relative opposing effects of the voltages applied to said input circuits, and means positioned by said motor for adjusting said biasing means until the effect of the electrodes is equal.

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