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1,438,976.

P. I. WOLD.
ELECTRIC REGULATOR.
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Fig. 1.

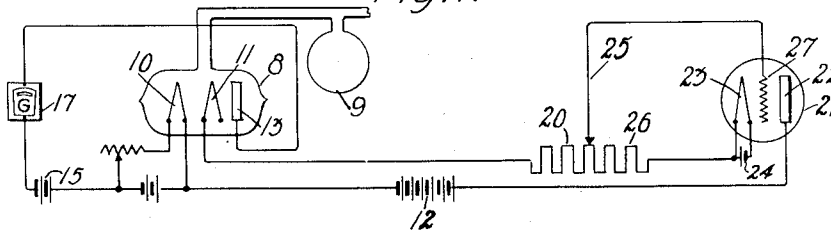


Fig. 2.

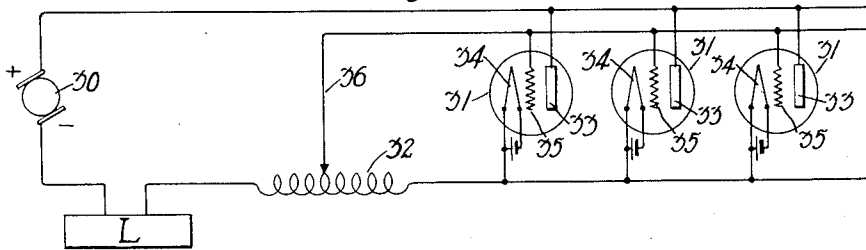


Fig. 3.

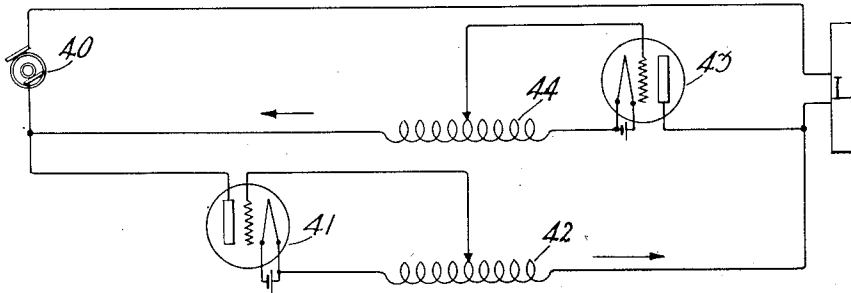
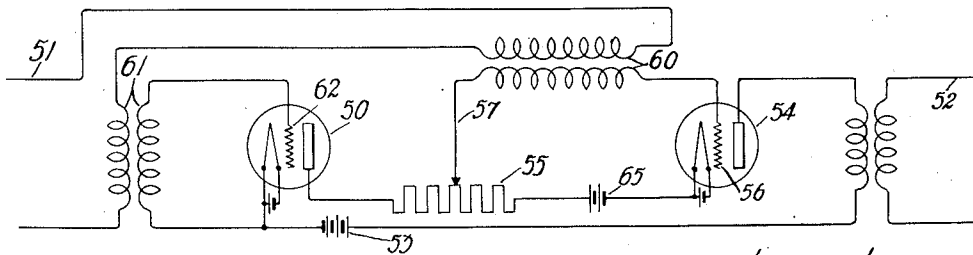


Fig. 4.



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ELECTRIC REGULATOR.

Application filed June 8, 1918. Serial No. 238,950.

To all whom it may concern:

Be it known that I, PETER IRVING WOLD, a citizen of the United States, residing at East Orange, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Electric Regulators, of which the following is a full, clear, concise, and exact description.

This invention relates to a novel type of regulator which is applicable in general for the regulation of electric circuits, and is particularly adapted to be employed for holding substantially constant the voltage or current in an electric circuit, or for controlling a mechanical or an electrical characteristic of a machine, such as the output of a generator or the speed of a motor.

One object of this invention is to provide a means of regulation as above set forth which shall be automatic, simple, efficient, light in weight and have a wide range of action.

Another specific object is to provide a regulating means in which a thermionic device is employed without the intermediary of electromagnetic means.

In accordance with this invention the desired regulation of the current or voltage in a system of electric distribution is accomplished by associating with the circuit to be regulated the electrodes of an evacuated vessel or thermionic device in such a manner that any variation in the current or voltage of the circuit will be compensated for by corresponding variations in the internal impedance of the vessel.

As is well known in the art, the internal impedance between the anode and cathode of a thermionic device of the three-electrode type depends upon the potential applied to the third electrode, which is usually called a grid,—and, within certain limits, the more positive its potential, the smaller the impedance between the anode and cathode.

One way the objects of this invention may be accomplished consists in inserting in the circuit to be regulated such a thermionic device and an impedance or resistance in series with said device, a portion of said resistance being included between the grid and the cathode. The potential of the grid will therefore depend upon the potential drop across the portion of the resistance included

between the grid and cathode and will allow a constant current to flow through the tube as long as the potential drop across the resistance remains steady. As soon as the potential drop across this resistance tends to change, the grid potential will change in such a manner as to cause the decrease or increase, as the case may be, of the impedance in the tube to compensate and practically annul the primary change in the characteristic of the circuit to be controlled.

In regulators hitherto employed it has generally been found necessary to employ one or more electromagnetic relays having their armatures under control of the fluctuations in the circuit to be regulated; but in such schemes objectionable sparking is liable to occur between the relay contacts. It is apparent from the above description, however, that such objectionable sparking does not occur in the regulator of this invention since no vibrating contacts are required for its operation.

This invention will be better understood by reference to the following detailed description taken in connection with the accompanying drawings, in which Fig. 1 represents this invention employed as a regulator for a vacuum gauge; Fig. 2 shows this invention in connection with a direct current generator, while in Fig. 3 this invention is applied to an alternating current generator. Fig. 4 illustrates this invention in connection with a telephone repeater to compensate for fluctuations that may occur in the local circuit of the repeater.

Referring more particularly to Fig. 1, 8 is a vacuum gauge which may be employed for measuring gas pressures in vessels such as 9 that are undergoing evacuation. This vacuum tube gauge is described in detail and claimed in the United States patent to Buckley No. 1,372,798, issued March 29, 1921, to which reference is made. Briefly stated, the action of the gauge depends upon the fact that when such a vessel is very highly evacuated, a practically pure electron current will flow between cathode 10 and anode 11 on applying the voltage from the battery 12 to these electrodes, and that practically none of this current will flow to the third electrode 13, since it is maintained at a negative potential with respect to the cathode 10 by

means of the source of voltage 15. If now gas is introduced in the vessel, positive ions will be produced and these positive ions will travel to that electrode which is most negative, that is, to the electrode 13. This flow will therefore give rise to a current through the galvanometer or indicator 17, the amount of which may be measured. Obviously, any change in the evacuation of the vessel 8 will produce a change in the number of positive ions flowing to the controller 13, therefore producing a change in the current reading of the instrument 17, so that its reading is an indication at any instant of the degree of evacuation within the vessels 8 and 9.

It is very desirable in such a system to maintain at a steady value the space current flowing between the anode and cathode, since fluctuations are liable to occur therein due, for example, to the changes in the degree of vacuum in the gauge or the temperature of the filament or the voltage of battery 12. Such fluctuations may be considerably decreased, if not practically eliminated, by the use of this invention which here consists in inserting in series with the electrodes of the vacuum gauge an impedance, which may be a resistance 20, and a thermionic device 21. The anode 22 of the tube 21 is connected to the battery 12 so as to be positive, while its cathode 23 is connected so as to be negative. A substantially constant current is supplied to the cathode 23 by the battery 24. A lead 25 for the grid is tapped at a suitable point on resistance 20 so that the grid is kept negative with respect to the cathode by the I R drop across that part 26 of the resistance which is included between the tap 25 and the cathode. The vacuum tube 21 accordingly offers a certain amount of impedance to the current flowing in the main circuit, which impedance has a value determined by the value of the resistance 26 and the characteristics of the tube 21. If a fluctuation in the current now arises, due to disturbances in any part of the circuit, such as a change in the voltage of the battery 12, or a change in the impedance of any other part of the circuit which causes a change in the current, there will be a certain corresponding change in the impedance of the vacuum tube 21; and the characteristics of the circuit as connected are such that this impedance change will oppose the fluctuations in the current flow. For example, suppose there is an increase in the voltage of battery 12 which tends to increase the potential drop along resistance 26, thereby rendering the grid 27 more negative with respect to the cathode. There will then result an increase in the impedance of the vacuum tube which will oppose the original increase in current, thereby tending to maintain the current constant.

From theoretical considerations it has been found that the effectiveness of the circuit ar-

range ment shown above to reduce fluctuations depends, to a considerable degree, upon the value of the resistance 26 and upon the amplifying power of the vacuum tube and in general it may be said that the greater the amplifying power of the tube the more complete will be the reduction of the fluctuations. Thus, for an amplifying power of 20, and a resistance in 26 equal to the resistance of the remainder of the circuit, the fluctuations in voltage may be reduced to less than one tenth of their original value, while with an amplifying power of 50, they may be reduced to less than one twenty-fifth of their original value.

In Fig. 2 the method of control illustrated in Fig. 1 is shown applied to a direct current generator 30 which is supplying current to a load L and it is desired to maintain a constant current through this load. In accordance with this invention one or a plurality of tubes 31, which may be connected in parallel, and an impedance 32 having appreciable inductance and resistance, are connected in series with the load, the anodes 33 being connected to the positive side and the cathodes 34 to the negative side of the generator. The grids 35 by lead 36 are kept at a negative potential with respect to the cathodes. The manner of the control of the current through the circuit is the same as that for Fig. 1. Any change in the current of the circuit, due to either a change in the output of the generator or due to a change in the impedance of the load L, will change the potential of the grids 35 in such a manner as to cause the resultant change in the internal impedance of the tubes to practically annul the primary change. Although the impedance 32 is shown as an inductive resistance and advantage is taken both of its inductive and its ohmic impedance, it is obvious that a pure ohmic resistance may be substituted therefor if desired, as was employed in the circuit arrangement of Fig. 1.

In Fig. 3, 40 is an alternating current generator supplying to a load L the current that is desired to be kept constant. As a thermionic device is essentially a unilateral device, for a circuit having an alternating current it is necessary to provide a device for both the positive and negative loops of the current in order that there may be complete regulation. Referring to the drawing one loop of the alternating current will pass through the tube 41 and inductive resistance 42, while the other loop will pass through tube 43 and inductive resistance 44, since positive current will flow only from the anode to the cathode of a thermionic device. The controlling action of each of the tubes is the same as in the preceding figures, but in this case care should be taken that the value of the inductive resistance

between the cathode and anode of each tube should not be sufficient to make the grids negative enough to reduce the space currents of the tubes to zero. The action of the arrangement then would be such that if the maximum current amplitude would tend to increase, the grids would become more negative, thereby reducing the increase; or if the maximum current amplitude would tend to decrease below the desired value, the grids would become less negative, thereby opposing the decrease. It follows, therefore, that the load L would be supplied with a current having a substantially constant maximum amplitude.

Fig. 4 shows this invention in connection with a telephone repeater 50 which is adapted to repeat currents from an incoming line 51 to an outgoing line 52. In the output circuit of the repeater in series with its source of voltage 53 is a vacuum tube 54 and a resistance 55. This arrangement, as above described, will choke out any fluctuations arising in the local circuit containing the vacuum tube, such as fluctuations as might be due to variations in the voltage from source 53. However, in order that this regulator 54 may not choke out at the same time the signals coming in from line 51 and which are reproduced in amplified form in the output circuit of the repeater, an additional transformer 60 is provided for impressing the signaling currents upon the grid 56 of the vacuum tube 54. Thus, when a positive impulse from line 51 is impressed on grid 62 by transformer 61, the current in the output circuit of the repeater would tend to increase, thereby increasing the potential drop in the resistance 55 which, being impressed on grid 56, would make it more negative and would tend to suppress this increase of current in the output circuit of the repeater. The coils of transformer 60, however, should be so related that the impulses impressed through transformer 61 to make grid 62 more positive also impresses a positive impulse on grid 56 of such a strength as to annul the change of potential of grid 56, due to the change in current flowing through resistance 55 which has been caused by the amplified positive impulse of the signal in the output circuit of the repeater. The regulator 54 is therefore made unresponsive to changes in the output circuit current of the repeater, which are due to incoming signals, but is responsive to fluctuations arising in the local circuit, such as fluctuations in the source 52, since in the latter case, no neutralizing charge will be impressed on grid 56 through transformer 60.

As shown in Fig. 4, a battery 65 may be inserted if desired between the grid and the filament of the regulator for controlling the value of the steady potential of the grid. It is obvious that the insertion of such a bat-

tery is applicable to any of the other figures.

It is obvious that this invention is not limited in its application and form to those above described, but that various modifications may be made therein by anyone skilled in the art without departing in any wise from the spirit of this invention as defined in the appended claims.

What is claimed is:

1. In combination, an electric machine, supply leads connected to said machine, a vacuum tube having an anode, a cathode and a control electrode, said anode and cathode being connected in circuit with said machine whereby said tube is supplied with space current from said leads, and a connection from said leads to said control electrode for varying the potential of said control electrode in response to changes in the current of said supply leads to control a condition of said machine.

2. The combination with a circuit to be regulated, of a vacuum tube associated therewith for regulating said circuit, said vacuum tube having an anode and a cathode, and a control electrode for controlling the space current between said anode and said cathode, an impedance element in series with said anode and cathode and responsive to a characteristic of said circuit, said control electrode being responsive to the drop in potential across the terminals of said impedance for varying a characteristic of said tube in such a manner as to cause the regulation of said circuit.

3. An electric circuit to be regulated comprising a source of voltage, a vacuum tube having a plurality of electrodes including an anode and a cathode, said anode and cathode being connected in said circuit in series with said source, and means comprising an impedance connected between two electrodes in said tube for causing said tube to be responsive to a condition of said circuit whereby said circuit may be regulated.

4. The combination with a circuit to be regulated, of an electric discharge device regulator therefor having an anode and a cathode, and a control electrode for controlling the space current between said anode and cathode, a source of voltage for said circuit, said source being connected between said anode and cathode, and means comprising an impedance connected between said control electrode and said cathode for controlling in response to a change in a characteristic of said circuit the space current of said regulator whereby the regulation of said circuit is obtained.

5. An electric circuit containing an electric machine, a thermionic regulator of the unidirectional type therefor and an impedance, said regulator having a plurality of electrodes, said impedance being in shunt to two of said electrodes, and said regulator

being responsive to the current in said circuit.

6. In combination, an electric machine, a resistance, a thermionic regulator comprising an anode and a cathode and a control electrode for controlling the space current between said anode and cathode, an electric circuit comprising said machine, said resistance, said anode and said cathode, and a connection for causing the potential of said control electrode to be responsive to the drop of potential across the terminals of said resistance whereby a change in a characteristic of said circuit is reduced to a low value by said regulator.

7. In combination, an electric discharge device having an anode, a cathode and a control electrode, a source of voltage connected in circuit with said anode and cathode and means for holding substantially constant an electrical characteristic of the space current path between said anode and cathode regardless of changes in said source, said means comprising connections responsive to said changes for varying the potential of said control electrode with respect to said cathode.

8. An electric circuit comprising an electric machine, a vacuum tube of the unidirectional type comprising an anode, a cathode, and a control electrode, an impedance between the negative terminal of said machine and said cathode and a connection from said control electrode to said impedance, said tube being supplied with space current from said machine.

9. An electric circuit comprising an electric machine, a vacuum tube having an anode, a cathode and a grid, an impedance in circuit with said machine, a connection from said anode to a point on said impedance, a connection from said cathode to a point on said impedance and a connection from said grid to a point on said impedance.

10. In combination, an electric generator, leads from said generator to a load circuit, a vacuum tube having an anode and a cathode and a control electrode for controlling the space current between said anode and cathode, an impedance, said impedance, said anode and said cathode being connected in series with one of said leads, said impedance being located electrically between said cathode and the negative pole of said generator, and a connection between said impedance and said control electrode.

11. In combination, an electric device to be regulated, leads from said device, a vacuum tube comprising an anode and a cathode and a control electrode for controlling the space current between said anode and cathode, an impedance; said anode, said cathode and said impedance being connected in series with said leads, and a connection between said

control electrode and said impedance whereby said tube holds substantially constant a characteristic of said device.

12. In combination, an electric device to be regulated, a vacuum tube having an anode and a cathode and a control electrode for controlling the space current between said anode and cathode, an impedance responsive to changes in a characteristic of said device, connections whereby the drop in potential across the terminals of said impedance controls the potential of said control electrode to determine the value of the space current of said tube, said device being connected in circuit between said anode and cathode whereby the resultant changes in the space current of said tube reduces the changes in a characteristic of said device to a low value.

13. The combination of a vacuum tube having an anode, a cathode and a control electrode, a source of space current for said tube, and means comprising said control electrode for holding said space current substantially constant regardless of changes of said source.

14. The combination of a vacuum tube having an anode, a cathode and a control electrode, a source of space current for said tube, an impedance in series with said source, said anode and said cathode, and a connection between a point on said impedance and said control electrode.

15. In combination, an electric device to be regulated, a vacuum tube having an anode and a cathode, and a control electrode for controlling the space current between said anode and cathode, and leads for connecting said device in circuit between said anode and cathode whereby a characteristic of said device is controlled by the intensity of the space current of said tube, said control electrode being directly connected through a direct current path to said device whereby a change in an electrical characteristic of said device so changes the potential of said control electrode as to reduce the change in an electrical characteristic of said device to a low value.

16. In combination, an electric device to be regulated, a vacuum tube having an anode and a cathode and a control electrode for controlling the space current between said anode and cathode, and leads for connecting said device in circuit between said anode and cathode whereby the value of an electrical characteristic of said device is determined by the space current of said tube, said control electrode being directly connected through a direct current path to said device whereby a change in a characteristic of said device so changes the potential of said control electrode that said change in an electrical characteristic of said device is reduced to a low value, said control electrode being so

connected externally to said cathode that said control electrode is always negative with respect to said cathode.

17. In combination, an electric generator, a vacuum tube having an anode and a cathode and a control electrode for controlling the space current between said anode and cathode, connections for supplying said tube with space current from said generator, and means responsive to changes in a characteristic of said generator for applying a potential to said control electrode whereby said changes are reduced to a low value.

18. In combination, an electric machine, supply leads for said machine, a vacuum tube having an anode, a cathode and a control electrode for controlling the space current between said anode and cathode, said anode and cathode being connected in circuit with said leads whereby said tube is supplied with space current from said leads, an impedance in circuit with said leads and responsive to changes in a characteristic of said machine, and a connection to said control electrode whereby said control electrode is responsive to the drop in potential in said impedance for changing said space current in such a manner as to reduce to a low value the changes in a characteristic of said machine.

19. In combination, an electric machine, supply leads connected to said machine, and means responsive to a condition of said leads for regulating said leads, said means comprising an impedance, a vacuum tube having an anode, a cathode and a control electrode, said anode, said cathode and said impedance being connected in series with said leads, and

a connection from said control electrode to one of said leads.

20. In combination, a source of voltage, supply leads from said source, and means for holding substantially constant the current from said leads, said means comprising a vacuum tube regulator having an anode, a cathode and a control electrode, and an impedance traversed by current from said source and having a connection to said cathode and a connection to said control electrode.

21. An electric circuit comprising a thermionic amplifier having an anode, a cathode and a control electrode, an impedance device in series with said anode and cathode, and a connection between said control electrode and said impedance for regulating a condition of said circuit.

22. In combination, an electric machine to be regulated, a variable impedance discharge device comprising an anode, a cathode and a control electrode, a direct connection between said anode and one terminal of said machine, a direct connection between said cathode and one terminal of said machine whereby said device is supplied with space current and whereby a variation in the impedance of said device produces a change in a characteristic of said machine, and a stationary connection to said control electrode for controlling the potential of said control electrode in response to variations in a characteristic of said machine.

In witness whereof, I hereunto subscribe my name this 5th day of June A. D., 1918.

PETER IRVING WOLD.