

ELECTRIC REGULATOR

Filed June 11, 1919

Fig. 1.

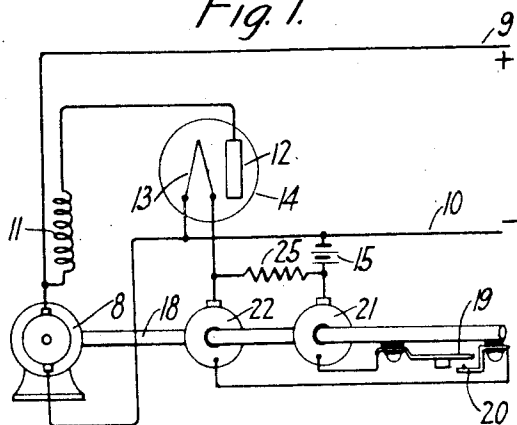


Fig. 2.

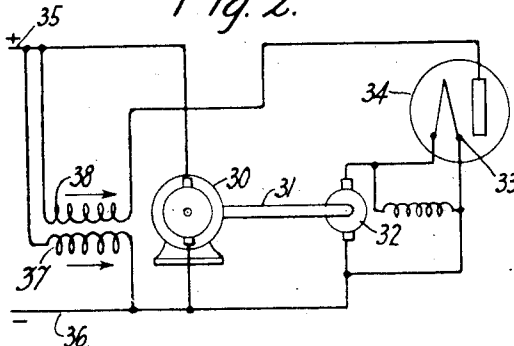


Fig. 3.

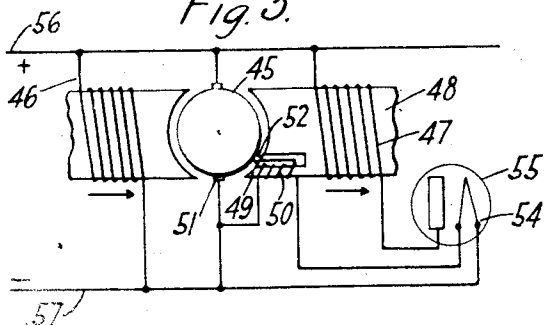


Fig. 4.

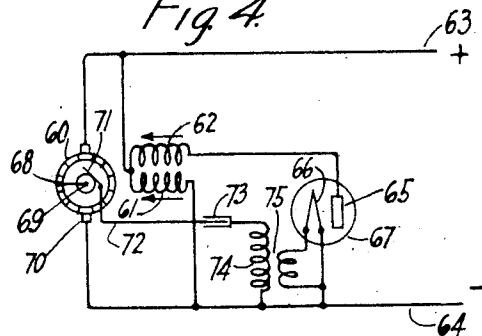
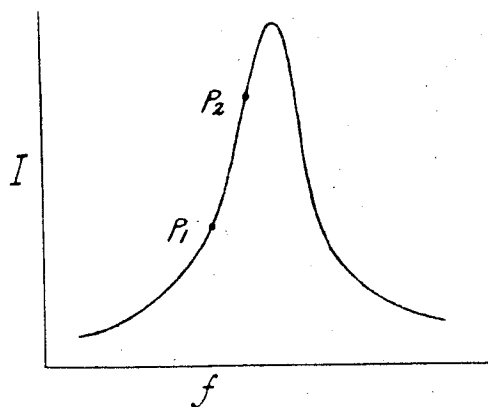


Fig. 5.



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UNITED STATES PATENT OFFICE

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ELECTRIC REGULATOR

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This invention relates to a novel type of regulator which is applicable in general for the regulation of electric circuits, and is particularly adapted for controlling a motor in order that its speed may be regulated.

The regulator provided according to the present invention is of the thermionic type and comprises a vacuum tube containing electrodes. As is well known in the art, the cathode of a vacuum tube serves as a source of electrons that travel to the anode or plate electrode and the amount of this electron stream or space current depends upon several factors, primarily upon the temperature of the cathode, an increase in temperature producing a larger space current. It is also well known that changes in the temperature of a cathode create much more than proportional changes of the space current, and consequently of the internal impedance of the tube, so that a vacuum tube may be made to respond very readily to changes in the temperature of the cathode.

In accordance with this invention a characteristic of an electrical machine such as the speed of a motor, may be regulated by connecting an exciting winding of the motor in circuit with the cathode and anode of the vacuum tube, and by supplying the cathode with heating current which varies with the speed of the motor or with the voltage supplied thereto. One way in which the heating current may be made to respond to the speed of the motor is to provide means for producing an alternating current which varies in frequency in accordance with changes in speed, and supplying the cathode with said current through the intermediary of a circuit tuned to a frequency preferably higher than the maximum frequency of said current. The intensity of the current in said tuned circuit will then depend upon the frequency of the current impressed thereon and consequently upon the speed of the motor. The temperature of the cathode and consequently the effective impedance of the tube will therefore respond to changes in the speed of the motor, so that the variations in the tube's impedance may so modify the current through an exciting winding of the mo-

tor as to bring about the desired regulation.

As is well known in the art, the space current of a vacuum tube at first increases very rapidly with increase in plate voltage but after a certain value of plate voltage, dependent upon the temperature of the cathode, is reached the space current remains substantially constant regardless of further increase in plate voltage. In utilizing a vacuum tube as a regulator it has been found preferable to have the tube operate on that part of the curve above described where a wide variation in plate voltage will not produce any appreciable change in the space current.

The electric regulator of the thermionic type possesses many advantages over regulators of other types in that it is simple, efficient, light in weight, and substantially free from sparking. Other advantages will be apparent from the detailed description of this invention.

Reference is made to the following copending applications which relate to regulators of the type employed in this invention: Hugh M. Stoller, Serial No. 230,192, filed April 22, 1918; Hugh M. Stoller, Serial No. 231,586, filed April 30, 1918; Hugh M. Stoller, Serial No. 244,636, filed July 12, 1918; Peter Irving Wold, Serial No. 238,950, filed June 8, 1918; Peter Irving Wold and Oliver E. Buckley, Serial No. 250,883, filed August 21, 1918; and Peter Irving Wold, Serial No. 247,275, filed July 29, 1918.

As a thermionic device may be associated with an electric motor in a variety of ways several forms that this invention may assume will now be described in detail in connection with the drawing, in which Fig. 1 illustrates the thermionic regulator of this invention applied to vary the current through an exciting winding of a motor in response to changes in its speed; in Fig. 2, the heating current for the cathode of the vacuum tube regulator is supplied by a small generator which is driven by the motor to be regulated; Fig. 3 is a modification of Fig. 2; in Fig. 4, the cathode of the thermionic regulator is supplied through a transformer with a heating current which varies with the speed of the motor; and Fig. 5 is a curve illustrating how the current in

a tuned circuit changes with the impressed frequency.

Fig. 1 shows how this invention may be applied to the regulation of the speed of a shunt-wound motor, 8 is a motor connected through mains 9 and 10 to a suitable power supply. In circuit with the exciting winding 11 of the motor are the anode 12 and cathode 13 of a vacuum tube 14. Heating current for the cathode 13 is supplied by a source of voltage 15. The current through the exciting winding 11 depends upon the temperature of the cathode 13, so that any change in the temperature of the cathode will vary the current through the exciting winding 11 and consequently vary the speed of the motor. Mounted on the axle 18 of the motor are a centrifugally controlled contact 19 and a relatively stationary contact 20 which are electrically connected to slip rings 21, 22 respectively. Brushes on these rings are connected to the terminals of a resistance 25 which is in circuit with the cathode 13 and battery 15. Contact 19 should be so designed as to close when the speed of the motor exceeds a predetermined value while breaking contact at a somewhat lower value, these two values preferably being the limitation of range of fluctuation permissible in the speed of the motor 8. For example, in a case where the normal speed of the motor is 1800 R. P. M., these upper and lower limiting values might be 1830 R. P. M. and 1770 R. P. M. respectively.

The manner in which the speed of the motor 8 may be controlled by such an arrangement may be explained as follows. If while the motor is running at normal speed, the voltage supply should suddenly be increased, or the load on the motor would decrease, there would be a tendency of the speed of the motor to increase. As soon as the speed of the motor reaches the upper limiting value mentioned above, which in the case illustrated is 1830 R. P. M., the contact 19 will close, thereby short-circuiting resistance 25 and increasing the current supplied to filament 13. This would decrease the impedance of tube 14 a more than proportional amount, thereby immediately increasing the current through exciting winding 11 and slowing up the speed of the motor. If, however, the speed would then decrease below the limiting value of 1770 R. P. M., contact 19 would be opened again, thereby decreasing the temperature of the cathode and increasing the speed of the motor. It follows that the contact 19 would be made and broken so as to maintain the average temperature of the cathode 13 at such a value as to give the substantial constant speed desired.

In the arrangement shown in Fig. 2, the motor 30 has mounted on its axle 31 a small generator 32 which supplies current to the cathode 33 of vacuum tube 34. Space current for the tube is supplied from the leads

35, 36 which also supply the motor 30. The motor is provided with a main field winding 37 and an aiding winding 38, winding 38 is in series with the electrodes of the vacuum tube 34. If now the speed of the motor would tend to increase, due for example, to an increase in the voltage across the leads 35, 36, the speed of the generator 32 would likewise tend to increase, thereby increasing the temperature of the cathode 33 and the space current through the tube and hence the current through the aiding winding 38, thus restricting the rising speed of the motor 30. Likewise a decrease of the voltage supplied to the motor would decrease the temperature of the cathode and the current flowing through the aiding winding, so that the speed of the motor may be maintained at the desired value.

Fig. 3 illustrates another form that this invention may take in being applied to the regulation of the speed of a direct current motor 45 which is a shunt-wound motor having a main exciting winding 46 and an auxiliary aiding winding 47. One pole 48 of the field magnet of the motor is shown slotted so as to form a separate pole piece 49 around which is a winding 50 shunted between one of the main brushes 51 and an additional brush 52. The winding 50 should preferably have more ampere turns than the winding 47. The motor, therefore, acts as a generator for supplying voltage across the terminals of this winding 50 which, as shown, may be also connected to heat the cathode 54 of the thermionic regulator 55. The anode of this vacuum tube is shown connected to a terminal of the aiding winding 47.

The manner in which the vacuum tube 55 may regulate the speed of the motor 45 may be explained as follows. When the voltage across the leads 56, 57 would increase, for example, thereby tending to speed up the motor, the voltage generated across the brushes 51, 52 would likewise increase, thereby increasing the temperature of the cathode 54. This temperature change would produce a more than proportional increase in the space current of the vacuum tube, so that the current through the aiding winding 47 would likewise be greater. This increase in the current in the auxiliary winding would tend to strengthen the motor field, thereby restricting the increase in the motor's speed. In a similar manner, if the voltage across leads 56, 57 would decrease in value, the thermionic regulator 55 would decrease the current through the field winding 47, thereby weakening the field and restricting the reduction in the speed.

In Fig. 4 the motor 60 has a main exciting winding 61 and an aiding winding 62 connected between the supply mains 63, 64. In circuit with the aiding winding 62 are the anode 65 and cathode 66 of the thermionic regulator 67. The motor 60 has one of its

commutator bars 68 grounded by having it electrically connected by a wire to axle 69. Connected between the main brush 70 and a brush 71 which bears on the axle is a circuit 72 containing a condenser 73 and the primary winding 74 of a transformer 75. When the motor 60 is running, it is evident that this circuit 72 would be supplied with a pulsating voltage which would be at a maximum value when the grounded commutator bar 68 is diametrically opposite brush 70 and zero in value when brush 70 is on the grounded commutator bar. The secondary winding of the transformer 75 is connected across the terminals of cathode 66. Since the current in this secondary winding is proportional to the current of the circuit 72, it follows therefore that the average temperature of the cathode 66 will be proportional to the strength of the alternating current in circuit 72. The frequency of this current will, of course, depend upon the speed of the motor, an increase in frequency being produced by an increase in speed.

As is well known in the art, the strength of the current in a circuit containing inductance and capacity is a maximum for the frequency of current to which the circuit is tuned and decreases rapidly in value as the frequency changes to other values.

Fig. 5 illustrates a characteristic curve such as the tuned circuit 72 may have in which the ordinates represent the intensity of the current in the circuit and the abscissae represent different values of the impressed frequencies. It is preferable that the tuned circuit 72 be tuned to a higher value of frequency than will be met in the regulation of the speed of the motor, so that the variation in frequency, due to changes in speed, would, for example, be within the range of the two points P_1 and P_2 on this curve. As may be seen from the drawing the curve is very steep between these two points, a small increase in frequency or speed of the motor producing a very large increase in the intensity of the current in the tuned circuit.

The manner in which the regulation is obtained in Fig. 4 may now be described as follows. With the tuning of circuit 72 so adjusted that the motor gives a frequency of current in the circuit of a value intermediate the points P_1 , P_2 on its characteristic curve, suppose that the speed of the motor would suddenly tend to increase. The frequency of the current in the circuit 72 would consequently increase, thereby producing a much greater change in its current value. This increase in current would be impressed through transformer 75 on the filament 66, increasing its temperature and increasing the current in the aiding winding 62. It follows, therefore, that any change in the speed of the motor would so change the current through the aiding winding 62 that the

change in speed of the motor would be restricted to a small value, thereby enabling the speed of the motor to be maintained at a substantially constant value in spite of changes in voltage, load, temperature or other circuit conditions.

With the arrangement shown in Fig. 4 it is important that the circuit 72 be tuned to such a frequency that the regulator 67 is able to so restrict any rise in speed of the motor that the current supplied to circuit 72 will never have a frequency as high as the frequency to which circuit 72 is tuned.

It is obvious that this invention is not limited to the particular forms above described, but that they may be considerably modified without departing in any wise from the spirit of this invention, as defined by the appended claims.

What is claimed is:

1. In combination, an electric circuit containing an electric machine having a stator and a rotor, a tuned circuit responsive to changes in a characteristic of said electric circuit, and means comprising a thermionic device responsive to the tuned circuit for regulating a characteristic of said electric circuit.

2. In combination, an electric machine having a stator and a rotor, a tuned circuit responsive to changes in a characteristic of said machine, and a vacuum tube regulator responsive to said circuit for regulating a characteristic of said machine.

3. In combination, an electric circuit containing an electric machine, a tuned circuit responsive to changes in a characteristic of said circuit, means comprising an electric discharge device having an anode and a cathode for regulating a characteristic of said circuit, and means for heating said cathode through the intermediary of said tuned circuit.

4. In combination, an electric motor, a tuned circuit responsive to changes in a characteristic of said motor, an electric discharge device regulator for controlling a characteristic of said motor and having a cathode, and means for causing the temperature of said cathode to be responsive to said tuned circuit.

5. An electric machine, a tuned circuit, means for supplying alternating current to said circuit dependent in frequency upon a characteristic of said machine, means comprising a vacuum tube having an anode and a cathode for regulating a characteristic of said machine, and means for varying the heating current for said cathode in response to variations in the current in said tuned circuit.

6. An electric motor, a tuned circuit, means for supplying an alternating current in said circuit dependent in frequency upon the speed of said motor, means comprising a vacuum tube having an anode and a cathode

for regulating the speed of said motor, and means for varying the heating current for said cathode in response to variations in the current in said tuned circuit.

5 7. A motor having an exciting winding, a vacuum tube in circuit with said winding, said vacuum tube having an anode and a cathode, and means for supplying said cathode with current which varies in frequency
10 in response to changes in the speed of said motor.

8. An electric machine having an exciting winding, a vacuum tube in circuit with said winding, said vacuum tube having an anode
15 and a cathode, means for supplying said cathode with current which varies in frequency in response to change in a characteristic of said machine.

9. In combination, a circuit to be regulated, a vacuum tube regulator therefor having
20 an anode and a filamentary cathode, a transformer, means for supplying to said cathode through said transformer alternating current varying in accordance with the characteristic
25 to be regulated, and means responsive to said tube for controlling said circuit.

10. An electric motor having a commutator and an exciting winding, a vacuum tube
30 in circuit with said exciting winding, said vacuum tube having an anode and a cathode, one of said commutator bars being electrically connected with the axle of said motor, a brush on said axle, a transformer, a condenser,
35 an electric circuit comprising the primary of said transformer, said condenser, said brush on the axle of said motor and one of the main brushes of said motor, and electric connections between said cathode and the secondary of said transformer.

11. An electric motor having an axle, a commutator and an exciting winding, a vacuum
40 tube in circuit with said winding, said vacuum tube having an anode and a cathode, an electrical connection between one of said commutator bars and said axle, a brush on
45 said axle, a transformer, a condenser, an electric circuit comprising the primary of said transformer, said condenser, a main brush of said motor and the brush on said
50 axle, whereby said circuit is supplied with a pulsating current of a frequency dependent on the speed of said motor, said circuit being tuned to a frequency greater than the frequency produced in said circuit by the normal
55 speed of said motor, and electrical connections between the cathode of said tube and the secondary of said transformer.

12. In combination, an electric machine having a stator and a rotor, a tuned circuit,
60 and means comprising a thermionic device responsive to fluctuations in a characteristic of said machine through the intermediary of said tuned circuit for regulating a characteristic of said machine.

65 13. In combination, a circuit to be regulated,

a vacuum tube regulator for controlling a condition of said circuit and having an anode and a cathode, a tuned circuit responsive to changes in a condition of said first circuit,
70 and means for supplying said cathode with heating current through the intermediary of said tuned circuit.

14. In combination, an electric circuit, a translating device in said circuit, and means
75 for holding substantially constant a characteristic of said device, said means comprising an electric discharge device having an anode and a cathode for controlling said electric circuit, a tuned circuit responsive to variations in a characteristic of said circuit, and connections responsive to said tuned circuit
80 for varying the discharge characteristics of said discharge device.

15. A motor regulating arrangement comprising, a motor to be regulated, means for
85 producing an alternating current having a frequency determined by the speed of the motor, a circuit over which said frequency may be transmitted, said circuit producing a large change in attenuation for a small
90 change in frequency, means to translate the alternating current into an operating current proportional to the attenuation, said means comprising an electron discharge device, and means controlled by said operating
95 current for varying the speed of said motor.

16. In combination, an electric machine having a stator and a rotor, a frequency selective circuit responsive to changes in characteristic of said machine, and a vacuum
100 tube regulator responsive to said circuit for regulating a characteristic of said machine.

17. In combination, an electric machine having a stator and a rotor, a circuit producing a large change in attenuation for a small
105 change in frequency, and a vacuum tube regulator responsive to said circuit for regulating a characteristic of said machine.

18. In combination an electric circuit, a translating device in said circuit and means
110 for holding substantially constant a characteristic of said device, said means comprising an electric discharge device having an anode and a cathode for controlling said electric circuit, a frequency selective circuit responsive to variations in a characteristic of
115 said circuit and connections responsive to said frequency selective circuit for varying the discharge characteristic of said discharge device.

19. In combination an electric circuit, a translating device in said circuit and means
120 for holding substantially constant a characteristic of said device said means comprising an electric discharge device having an anode and a cathode for controlling said electric circuit, a circuit producing a large change in attenuation for a small change in frequency responsive to variations in a charac-
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teristic of said circuit and connections responsive to said last mentioned circuit for varying the discharge characteristic of said discharge device.

5 In witness whereof, I hereunto subscribe my name this 9th day of June A. D. 1919.

HUGH M. STOLLER.

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