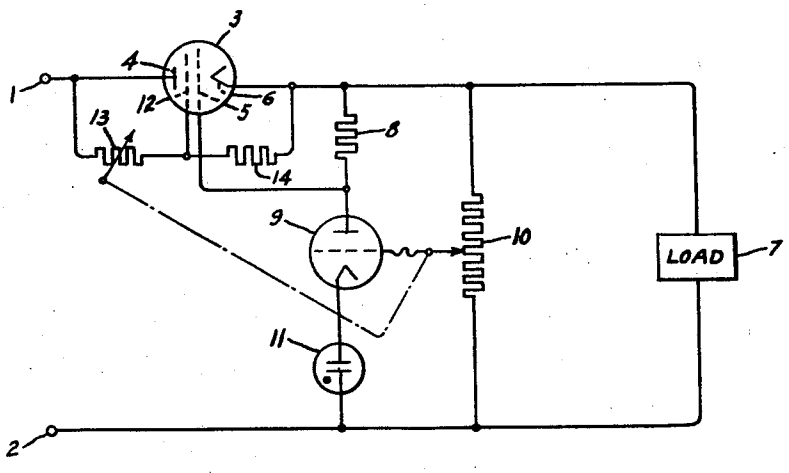
July 13, 1948. W. S. GRAFF-BAKER 2,445,171

REGULATOR

Filed Jan. 29, 1946



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Patented July 13, 1948 2,445,171

UNITED STATES PATENT OFFICE

2,445,171

REGULATOR

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Application January 29, 1946, Serial No. 644,142
In Great Britain May 30, 1945

4 Claims. (Cl. 323—22)

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My invention relates to electron tube regulators and more particularly to regulators employing a series connected electron tube between a voltage source and load circuit.

A frequently used method of controlling an electrical or mechanical condition at a load consuming electrical energy consists of varying the grid bias of a series connected electron tube in accordance with the load condition to be maintained. The value of the controlled quantity in a regulator of this type may be altered by adjusting the circuits feeding the grid of the series connected control tube. Variation of the controlled quantity in this manner has, however, been found usable only within the region of operation wherein the control tube is not saturated. Beyond this point, the control exercised by the grid of the series connected tube is not sufficient to maintain the necessary degree of constancy of the regulated quantity and satisfactory performance is not possible.

In the case of a voltage regulator employing a series connected electron tube, for instance, the constancy of voltage at the regulator output is very good when the desired output voltage is related to the source voltage and the load current in a manner that causes the control tube to operate in a region of its characteristics where control exercised by the grid is most effective. On the other hand, if an attempt is made to hold constant a load voltage which, for the source voltage and load current involved, requires the tube to operate in a region where control exercised by the grid is relatively ineffective, the actual regulated voltage deviates by a relatively large amount from the desired value. Thus the circuit performs as an effective regulator of voltage under some conditions of load current, output voltage, and input voltage and a relatively poor regulator of voltage under other conditions.

It is an object of my invention to provide an electron tube regulator capable of regulation over a wide range of adjustment of the regulated quantity.

It is a further object of my invention to provide in an electron tube regulator means to adjust regulated load quantity over a large range and which permits use of inexpensive standard circuit components in a simple and efficient manner.

An additional object of my invention is to provide an electron tube regulator capable of maintaining constant voltage over a wide range of load impedance, input voltage, and output voltage adjustment.

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Still another object of my invention is to automatically control an electron tube type regulator in order to achieve maximum performance of the circuit components used therein.

Briefly, I avoid the above-mentioned loss in control of a series connected tube by the use of an auxiliary grid, in that tube, the potential of the auxiliary grid being varied in accordance with the desired value of the controlled quantity. By utilizing a tube of this type, together with suitable resistances for control of the voltage of the auxiliary grid, I achieve a regulating circuit capable of maintaining a load quantity at a desired value even though the desired value of that quantity and the characteristics of the load are varied over a large range.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawings in which the figure shows an illustrative embodiment of a voltage regulator constructed in accordance with my invention.

In this figure a voltage regulating circuit adapted to maintain constant voltage at load 7 is shown. It consists of control tube 3 having its anode 4 connected to the positive supply terminal 1 and its cathode 6 connected to the positive side of load 7. Control grid 5 of tube 3 derives potential from the series circuit comprising resistance 8, tube 9, and gas discharge tube 11. The grid of tube 9 derives its bias from potentiometer 10 connected directly across load 7, together with the voltage drop across gas discharge tube 11.

Operation of the voltage regulating circuit of the figure is similar to that of a closed cycle control system or an amplifier having a large value of negative feedback. Any tendency for the load voltage to increase causes the grid of tube 9 to swing positive, thereby raising the grid potential with respect to the relatively constant cathode potential achieved by the use of gas discharge tube 11. This grid bias change increases the current flow through resistance 8 and causes grid 5 of tube 3 to swing negative with respect to cathode 6. Inasmuch as this increases the effective value of the space path resistance of tube 3, a lower voltage appears across load 7 and the initially high load voltage is reduced. If the voltage across load 7 decreases, the opposite effect

takes place and the equivalent resistance of the space path across tube 3 is reduced, thereby increasing the load voltage.

It is well known that the degree of regulation obtained in a closed cycle control system or a system having negative feedback is determined by the amplification in the feedback path, the regulated quantity being most nearly the desired value with high amplification. In the circuit of the figure, the total amplification in the feedback path is determined by the characteristics of tubes 3 and 9. In particular, the slope of the space current-grid bias characteristic of tube 3 exerts a considerable influence in this amplification since it is this tube that finally must vary load voltage. The value of this slope is determined by the tube characteristics and for large values of grid bias is very small. It is for this reason that the conventional regulating circuit shown in the figure achieves good regulation when the required grid bias at tube 3 is small and relatively poor regulation when the required grid bias is large.

In the circuit of the figure, the value of regulated voltage across load 7 is determined by the adjustment of potentiometer 10 inasmuch as this adjustment establishes the load voltage required for various values of grid bias at tube 9. This adjustment, however, can only be made throughout the region wherein the control exercised by control grid 5 of tube 3 is effective. Hence, while a large range of control may be achieved theoretically, only a limited degree of adjustment of the regulated voltage across load 7 is actually provided, the limit of regulation being determined by the allowable degree of error and the characteristics of the tubes used. For applications wherein a wide range of stabilized voltage must be attained or the load impedance varies greatly, this circuit is not satisfactory.

In the preceding description I have described the circuit of the figure as used as a conventional prior art voltage regulating device.

In accordance with my invention there is added, in addition to the above described components, an auxiliary grid 12 in tube 3 and resistances 13 and 14, the latter components providing a voltage divider by which the potential of auxiliary grid 12 is established in relation to the total voltage drop across tube 3.

With the circuit of my invention, adjusting potentiometer 10 alters the value of the regulated voltage in the same manner as described above for the circuit of the prior art. In addition, however, the value of resistance 13 is simultaneously changed either by separate manual adjustment or by a mechanical connection with potentiometer 10. This adjustment alters the potential of auxiliary grid 12 of tube 3 with respect to anode 4 and cathode 6. Optimum performance of the regulator is secured if resistance 13 is relatively low in value when the total potential drop across tube 3 is small, and large in value when the total potential drop is high. Hence, when potentiometer 10 is adjusted for a relatively high load voltage (low voltage drop across tube 3), tube 3 operates essentially as a triode and the control attained is achieved entirely by control grid 5. On the other hand, when potentiometer 10 is adjusted to provide a low load voltage (a high space path voltage drop across tube 3), resistance 13 is a relatively large value and auxiliary grid 12 aids control grid 5 in establishing the necessary voltage drop. This reduces the negative bias of control grid 5 required to achieve the necessary space path resistance of tube 3, thereby limiting the current flow which must take place through the series circuit comprising resistance 8, the space path of tube 9, and gas discharge tube 11. Inasmuch as a small current flow through tube 9 is required, the grid potential of tube 9 may be nearly equal the cathode potential and the difference between the actual voltage at the load 7 and the desired voltage is reduced.

Viewed differently, the changed relative grid bias of tube 3 when resistance 13 is altered in accordance with the setting of potentiometer 10 causes tube 3 to continue to operate in a region of high amplification with respect to the control grid even though there is a large space path voltage drop. Hence, amplification in the feedback path is maintained and a correspondingly small error exists between actual voltage and the desired regulated voltage.

While I have shown herein and have described in detail the application of my invention to a particular voltage regulating circuit, it is not limited thereby for it may be applied to all types of electron tube regulators wherein a series connected tube is utilized to control the regulated quantity and provision is made to alter, at will, the value of this quantity. It will be obvious, for instance, that if a regulator such as that of the figure be adapted to hold load current rather than the load voltage at a constant predetermined value, variable resistance 13 need only be changed in accordance with the changes in the desired value of regulated current. Similarly, if the regulator is adapted to maintain some other load characteristic, the potential of the grid of the series connected tube relative to the total space path voltage drop therethrough need only be changed in accordance with changes in the desired value of the regulated quantity.

While I have shown and described my invention as applied to a particular system of connections and as embodying various devices diagrammatically shown, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electron discharge regulator comprising, in combination, a voltage supply, a load, an electron discharge device in series circuit relation between said supply and load having at least an anode, a cathode, a control grid, and an auxiliary grid, means for selecting a desired value of load characteristic, means responsive to deviation from said desired characteristic to vary the bias of said control grid in a sense tending to maintain constant said desired characteristic and means to vary said auxiliary grid concurrently with said first means to provide a cumulative regulation of said load.

2. An electron discharge regulator comprising, in combination, a direct voltage source, a load, an electron discharge device having an anode, cathode, control grid and auxiliary grid, the anode-to-cathode path of said device being connected to series circuit between said source and load, means for impressing a direct control voltage on said control grid which is proportional to a desired load characteristic, said voltage having a polarity to vary the impedance of said device in a sense to oppose variations in said characteristic, means for impressing an operating bias

on said auxiliary grid such that said device operates in a region of relatively high amplification, means for independently adjusting the value of said control grid bias to adjust said impedance, and means for simultaneously adjusting said operating bias in direction tending to maintain said high amplification.

3. An electron discharge regulator comprising, in combination, a direct voltage source, a load, an electron discharge device having an anode, cathode, control grid and auxiliary grid, the anode-to-cathode path of said device being connected in series circuit between said source and load, means for impressing a direct control voltage on said control grid which is proportional to a desired load characteristic, said voltage having a polarity to vary the impedance of said device in a sense to oppose variations in said characteristic, means for impressing an operating bias on said auxiliary grid and means for simultaneously adjusting said control voltage and said operating bias in the same sense.

4. A direct voltage regulator comprising, in combination, a direct voltage source, a load, a first electron discharge device having at least an anode, cathode, a first grid and a second grid,

the anode to cathode path of said device being connected in series circuit between said source and load, a first potentiometer connected across said load, means comprising a second electron discharge device having a control grid connected to said first potentiometer for developing a first control voltage, means for impressing said control voltage on said first grid to vary the impedance of said path in a sense to oppose load voltage variations, a second potentiometer connected in shunt to said first discharge device, means for impressing a second control voltage on said second grid from said second potentiometer, means for simultaneously adjusting said two potentiometers to adjust said two control voltages in the same direction.

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