

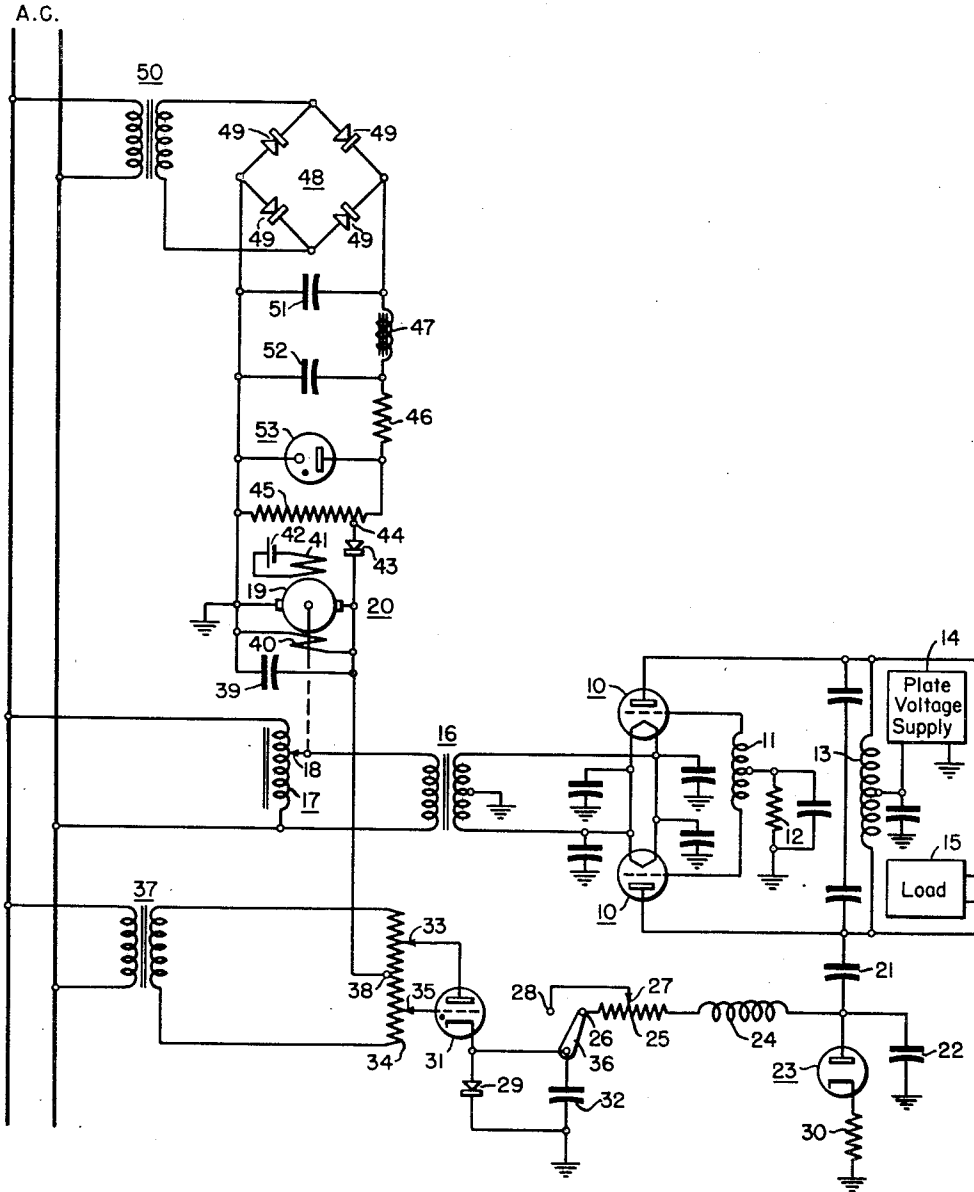
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RADIO APPARATUS

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RADIO APPARATUS

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1

This invention relates to automatic voltage controls for radio frequency generators, and relates more particularly to controls for maintaining constant the radio frequency voltages of generators having variable loads, such as those used in induction and dielectric heating systems.

In systems using radio frequency generators such, for example, as induction and dielectric heating systems, it is desirable to maintain a constant power density in the load regardless of changes in the projected area of the load. This is especially important in dielectric heating systems using conveyors where large load changes frequently occur.

Load changes cause changes in the radio frequency output voltages of the generators. If a generator has been adjusted to supply a predetermined power into its load, then if the load is reduced, the radio frequency voltage of the generator will increase. By maintaining the radio frequency voltage of a generator constant, the power supplied to its load can be maintained constant.

Prior systems for maintaining the output voltages of radio frequency generators constant have used relays which were energized in one direction upon increases in the radio frequency voltage of the generators to actuate contacts for closing circuits for decreasing the voltages, and which were energized in the opposite direction upon decreases in the radio frequency voltage to actuate contacts for closing circuits for increasing the voltages. Such systems have had the disadvantages that control over a wide range could be accomplished only in steps, and that hunting sometimes occurred.

This invention provides a voltage stabilizer which is continuous in action over a wide range and in which relays are not used.

In one embodiment of this invention, radio frequency current from the output circuit of a generator is rectified and used to bias a thyatron tube which supplies a direct current, the average value of which varies with variations in the radio frequency voltage, to the armature winding of a reversible motor which adjusts the filament voltage of the oscillator tubes of the generator. Current from a constant voltage, direct current, supply source is applied in opposite polarity to the armature winding. Undesired decreases in the radio frequency voltage of the generator, caused by increases in its load, cause the thyatron tube to supply currents to the armature of the motor which are smaller than that supplied by the direct current source, causing the motor to be en-

2

ergized to rotate in a direction to increase the voltage supplied to the filaments of the oscillator tubes, and to thereby increase the radio frequency voltage of the generator. Undesired increases in the radio frequency voltage of the generator, caused by decreases in its load, cause the currents supplied by the thyatron tube to the armature of the motor to be larger than the current supplied by the direct current source, causing the motor to be energized to rotate in the opposite direction to decrease the voltage supplied to the filaments of the oscillator tubes, and to thereby decrease the radio frequency voltage.

An object of the invention is to maintain a constant voltage in the output circuit of a radio frequency generator.

Another object of the invention is to provide a voltage stabilizing system for a radio frequency generator which will operate over a wide range of voltages.

Another object of the invention is to provide a voltage stabilizing system for a radio frequency generator which will operate without hunting.

The invention will now be described with reference to the drawing which is a circuit schematic illustrating one embodiment of the invention.

The radio frequency generator, the output voltage of which is to be maintained constant, comprises the push-pull connected oscillator tubes 10 having their grids connected together through the inductor 11, the center point of which is connected through the resistor 12 to ground. The plates of the tubes are connected together by the tank inductor 13, the center point of which is connected to the positive terminal of a conventional, plate voltage, supply source 14. The plates of the oscillator tubes are also connected to a load 15 which may be a dielectric heating load, an induction heating load, or any other form of load with which radio frequency generators are used.

The filaments of the oscillator tubes 10 are connected together and to the secondary winding of the filament transformer 16. The primary winding of the transformer has one end connected to one end of the conventional auto-transformer 17, and its other end connected to the slider 18 of the auto-transformer. The auto-transformer is connected to a conventional alternating current source, and its slider 18 is arranged to be adjusted by the rotation of the armature 19 of the electric motor 20 for varying the voltage supplied to the filaments of the oscillator tubes.

The plate of one of the oscillator tubes 10 is connected through the series connected voltage dividing capacitors 21 and 22 to ground, the junction point of the capacitors being connected to the plate of the diode rectifier tube 23. The plate of the tube 23 is connected to one end of the radio frequency choke 24, the other end of which is connected to one end of the resistor 25, and the other end of which terminates in the contact 26. The slider 27 of the resistor 25 is connected to the contact 28. The cathode of the tube 23 is connected through the resistor 30 to ground.

The switch 36 which is adapted to contact either the contact 26 or 28, is connected to the cathode of the thyatron tube 31, and through the capacitor 32 to ground. The selenium rectifier 29 is shunted across the capacitor 32. The plate of the tube 31 is connected to the slider 33 of the resistor 34, and its grid is connected to the slider 35 of the resistor 34. The resistor 34 is shunted across the secondary winding of the transformer 37, the primary winding of which is connected to the alternating current source.

The resistor 34 is tapped at 38, the tap being connected to one side of the armature winding 40 of the reversible, direct current motor 20, the other side of the armature winding being connected to ground. The by-pass capacitor 39 is shunted across the winding 40. The field winding 41 of the motor is energized by a suitable source of direct current illustrated as the battery 42. The armature 19 is adapted to be rotated in one direction by direct current supplied from the tube 31 as will be described.

The ungrounded side of the armature 40 is also connected through the selenium rectifier 43 to the tap 44 on the resistor 45, one end of which is connected to the grounded side of the armature winding 40, and the other end of which is connected through the series connected resistor 46 and filter choke 47 to one output side of the rectifier 48 which includes the four selenium rectifiers 49 connected in a conventional bridge circuit, the other output side of the rectifier 48 being connected to the grounded end of the resistor 45. The input side of the rectifier 48 is connected to the secondary winding of the transformer 50, the primary winding of which is connected to the alternating current source.

The capacitors 51 and 52 connected to the opposite ends of the choke 47 and to ground, are filter condensers. The voltage regulating tube 53 is connected across the resistor 45.

The rectifier 48 is a source of constant voltage, direct current, which supplies current of opposite polarity to that provided by the thyatron tube 31, to the armature winding 40 of the motor 20, for causing its armature 19 to rotate in the opposite direction to that caused by the current from the thyatron tube as will be described.

The selenium rectifiers 29 and 43 provide unidirectional current flow in their respective circuits.

In operation, the rectifier tube 23 rectifies radio frequency current from the tank circuit of the oscillator tubes, and supplies the rectified current through the radio frequency choke 24 and the resistor 25 and switch 36, to charge the capacitor 32 which is connected to the cathode of the thyatron tube 31, negatively. The tube 31 is so biased from resistor 34 so that it does not conduct until its cathode becomes sufficiently negative with respect to its grid as the charge in the capacitor 32 increases. At a predetermined negative charge in the capacitor, the tube 31 conducts, and rectified current from its plate

circuit flows through the armature winding 40 of the motor 20. Current of opposite polarity from the rectifier 48 also flows through the armature winding 19. It is understood that, if desired, instead of obtaining the bias for tube 31 from resistor 34 a separate fixed bias may be provided for tube 31.

The time required for the capacitor 32 to charge up to the firing voltage of the tube 31 depends upon the equation $C(R_1 + R_2)$ where C is the capacity of the capacitor 32 in farads; R_1 is the resistance of the resistor 25 in ohms, and R_2 is the resistance of the resistor 30 in ohms. Variation of the radio frequency current from the radio frequency generator supplied to the rectifier tube 23, causes variation of the current flow through the resistors 25 and 30 which, in turn, varies the time required for the capacitor 32 to charge up to the firing voltage of the tube 31. The discharge time of the capacitor 32 is, however, the same at all times.

After each firing of the tube 31, the capacitor 32 is discharged so that the tube 31 is blocked by its grid voltage until the capacitor 32 is again charged to the firing voltage of the tube, this cycle being repeated. In this way, radio frequency voltage variations cause corresponding variations in the rectified current through the tube 31. Although the pulse of rectified current is the same each time, the average current will depend upon the time required to charge the capacitor 32.

Assuming that the radio frequency generator has been adjusted to supply a constant power, which, by way of example may be 100 kilowatts, into the load 15, and the current from the tube 31 has been adjusted by adjustment of the sliders 33 and 35 along the resistor 34, until it is equal to the current of opposite polarity from the rectifier 48, then no current will flow through the armature winding 40, and the motor 20 will not operate.

Now assume that the load on the generator decreases so that the radio frequency voltage increases above its normal value. Then the rectified radio frequency current from the tube 23 will charge the capacitor 32 at a faster rate causing the tube 31 to conduct at a corresponding faster rate, and to supply an average current to the armature winding 40 which is greater than that supplied by the rectifier 48. This will provide a current flow through the armature winding in a direction to adjust the slider 18 along the auto-transformer 17 for decreasing the voltage supplied by the transformer 16 to the filaments of the oscillator tubes 10. This reduction in filament voltage will cause the tank radio frequency voltage to decrease, and will consequently cause the power supplied to the reduced load to be decreased to normal.

When the load on the generator increases, its tank radio frequency voltage will decrease below normal, causing the current supplied by the thyatron tube 31 to the armature winding 40 to be less than that supplied by the rectifier 48, so that current will flow through the armature winding 40 in a direction to cause its armature to rotate to move the slider 18 of the auto-transformer to increase the voltage supplied by the transformer 16 to the filaments of the oscillator tubes 10. This increase in the filament voltage of the oscillator tubes will cause an increase in the radio frequency voltage and a resulting increase in the power output of the generator.

Thus with an increase in the radio frequency

voltage from the generator, the rectified current from the rectifier tube 23 increases and decreases the charging time of the capacitor 32. This causes an increase in the average rectified current through the thyatron tube 31, and causes current flow through the motor armature winding 40 in a direction to cause the motor to act to decrease the voltage supplied to the filaments of the oscillator tubes 10. With a decrease in radio frequency voltage, this process is reversed.

The slider 27 of the resistor 25 and its contact 28 are provided so that more than one range of radio frequency voltages may be maintained. By placing the switch 36 on the contact 26, 20,000 volts, by way of example, may be maintained. By placing the switch 36 on the contact 28 and by adjusting the slider 27 along the resistor 25, radio frequency voltages of 10,000 volts and lower may be maintained.

I claim as my invention:

1. A voltage stabilizing system for a radio frequency generator, comprising means for varying the voltage of the radio frequency output current of the generator; a reversible motor for adjusting said voltage varying means; means for rectifying radio frequency current from the generator; means utilizing variations in the rectified current for providing a direct current which varies conformably therewith; a direct current source of constant voltage, and means conducting said first mentioned direct current and conducting current from said direct current source in opposite polarity to said motor for energizing same to rotate in one direction when said first mentioned direct current is greater than the current from said direct current source, and for energizing said motor to rotate in the opposite direction when said first mentioned direct current is smaller than the current from said direct current source.

2. A voltage stabilizing system for a radio frequency generator including an oscillator tube having a filament and a plate; a source of current for said filament; means including a reversible motor for varying the voltage supplied by said source to said filament; means for rectifying radio frequency current from the generator; means utilizing variations in the rectified current for providing a direct current which varies conformably therewith; a direct current source of constant voltage, and means conducting said first mentioned direct current and conducting current from said direct current source in opposite polarity to said motor for energizing same to rotate in one direction when said first mentioned direct current is greater than the current from said direct current source, and for energizing said motor to rotate in the opposite direction when said first mentioned direct current is smaller than the current from said direct current source.

3. A voltage stabilizing system for a radio frequency generator, comprising means for varying the voltage of the radio frequency output current of the generator; a reversible motor for adjusting said voltage varying means; a rectifier connected to said generator for rectifying radio frequency current therefrom; an electron tube; a power supply source connected through said tube to said motor; means utilizing the rectified radio frequency current from said rectifier for impressing upon said tube a potential causing it to conduct and to supply direct current from said source to said motor, and a direct current source of constant voltage, connected to said motor in polarity opposition to the current from said tube, said

motor being energized to rotate in one direction when the current from said tube is greater than the current from said source, and being energized to rotate in the opposite direction when the current from said tube is less than the current from said source.

4. A voltage stabilizing system for a radio frequency generator, comprising means for varying the voltage of the radio frequency output current of the generator; a reversible motor for adjusting said voltage varying means; a rectifier having an anode; means for supplying radio frequency current from said generator to said anode; a capacitor having one side connected to said anode; a gaseous electron tube having a grid, a cathode, and an anode, means connecting the cathode of said tube to the other side of said capacitor; a power supply source connected to said grid and anode of said electron tube and to said motor, said electron tube conducting and supplying direct current to said motor when said capacitor has been charged to a predetermined voltage, and a direct current source of constant voltage connected to said motor in polarity opposition to the current supplied by said tube to said motor, said motor being energized to rotate in one direction when the current from said tube is greater than the current from said source, and being energized to rotate in the opposite direction when the current from said tube is less than the current from said source.

5. A voltage stabilizing system for a radio frequency generator, comprising means for varying the voltage of the radio frequency output current of the generator; a reversible motor having an armature winding for adjusting said voltage varying means; means for rectifying radio frequency current from said generator; means utilizing the rectified current for supplying pulses of direct current the frequency of which is proportional to the value of the rectified current, to said armature winding, and a direct current source of constant voltage connected to said winding in opposite polarity to said direct current pulses, said motor being energized to rotate in one direction when the average value of the said pulses is greater than the direct current from said direct current source, and being energized to rotate in the opposite direction when the average value of said pulses is less than the current from said direct current source.

6. A voltage stabilizing system for a radio frequency generator including an oscillator tube having a filament, comprising a source of current for said filament; means including a reversible motor having an armature winding for adjusting the voltage supplied to said filament by said source; means for rectifying radio frequency current from said generator; means utilizing the rectified current for supplying pulses of direct current the frequency of which is proportional to the value of the rectified current to said armature winding, and a direct current source of constant voltage connected to said winding in opposite polarity to said direct current pulses, said motor being energized to rotate in one direction when the average value of the same pulses is greater than the direct current from said direct current source, and being energized to rotate in the opposite direction when the average value of said pulses is less than the current from said direct current source.

7. A voltage stabilizing system for a radio frequency generator, comprising means for varying the voltage of the radio frequency output current

of the generator; a reversible motor having an armature winding for adjusting said voltage varying means; a rectifier for rectifying radio frequency current from said generator; means including a gaseous electron tube for supplying direct current to said winding; means utilizing the rectified current from said rectifier for causing said tube intermittently to conduct and to supply direct current pulses to said winding at a frequency which is proportional to the value of the rectified current; and a direct current source of constant voltage connected to said winding in opposite polarity to said direct current pulses, said motor being energized to rotate in one direction when the average value of the said pulses is greater than the direct current from said direct current source, and being energized to rotate in the opposite direction when the average value of said pulses is less than the current from said direct current source.

8. A voltage stabilizing system for a radio frequency generator including an oscillator tube having a filament, comprising a source of current for said filament; means including a reversible motor having an armature winding for adjusting the voltage of the current supplied by said source to the filament; a rectifier for rectifying radio frequency current from said generator; means including a gaseous electron tube for supplying direct current to said winding; means utilizing the rectified current from said rectifier for causing said tube to intermittently conduct and to supply direct current pulses to said winding at a frequency which is proportional to the value of the rectified current; and a direct current source of constant voltage connected to said winding in opposite polarity to said direct current pulses, said motor being energized to rotate in one direction when the average value of said pulses is greater than the direct current from said direct current source, and being energized to rotate in the opposite direction when the average value of said pulses is less than the current from said direct current source.

9. A voltage stabilizing system for a radio frequency generator, comprising means for varying the voltage of the radio frequency output current of the generator; a reversible motor having an armature for adjusting said voltage varying means; a rectifier for rectifying radio frequency current from said generator; means including a gaseous electron tube for supplying direct current to said armature winding; means including a capacitor connected to said rectifier and to said tube for biasing said tube to intermittently conduct at a rate proportional to the value of the rectified current from said rectifier; a rectifier for rectifying radio frequency current from said generator; means utilizing the rectified current from said rectifier for causing said tube to intermittently conduct and to supply direct current pulses to said winding at a frequency which is proportional to the value of the rectified current; and a direct current source of constant voltage connected to said winding in opposite polarity to said direct current pulses, said motor being energized to rotate in one direction when the average value of said pulses is greater than the direct current from said direct current source, and being energized to rotate in the opposite direction when the average value of said pulses is less than the current from said direct current source.

10. A voltage stabilizing system for a radio frequency generator, comprising means for vary-

ing the voltage of the radio frequency output current of the generator; a reversible motor having an armature winding for adjusting said voltage varying means; a rectifier having an anode for rectifying radio frequency current from said generator; a capacitor having one side connected to said anode; a gaseous electron tube having a cathode, a grid and an anode; means connecting the other side of said capacitor to said cathode; a power supply source for said tube, a resistor shunted across said source; means connecting said grid and said anode of said tube to different points along said resistor; means for supplying direct current from said tube when it conducts to said armature winding, and a direct current source of constant voltage connected to said armature winding in opposite polarity to the current from said tube, said motor being energized to rotate in one direction when the current from the said tube to said winding is greater than the current from said direct current source to said winding, and being energized to rotate in the opposite direction when the current from said tube to said winding is less than the current from said direct current source to said winding.

11. A voltage stabilizing system for a radio frequency generator including an oscillator tube having a filament, comprising a source of current for said filament; means including a reversible motor having an armature winding for adjusting the voltage of the current supplied by said source to said filament; a rectifier having an anode for rectifying radio frequency current from said generator; a capacitor having one side connected to said anode; a gaseous electron tube having a cathode, a grid and an anode; means connecting the other side of said capacitor to said cathode; a power supply source for said tube, a resistor shunted across said source; means connecting said grid and said anode of said tube to different points along said resistor; means for supplying direct current from said tube when it conducts to said armature winding; and a direct current source of constant voltage connected to said armature winding in opposite polarity to the current from said tube, said motor being energized to rotate in one direction when the current from the said tube to said winding is greater than the current from said direct current source to said winding, and being energized to rotate in the opposite direction when the current from said tube to said winding is less than the current from said direct current source to said winding.

12. A voltage stabilizing system for a radio frequency generator, comprising means for varying the voltage of the radio frequency output current of the generator; a reversible motor having an armature winding for adjusting said voltage varying means; a rectifier tube having an anode connected to receive radio frequency current from said generator, and having a cathode, a resistor connected to said cathode and to ground; a gaseous electron tube having a grid, a cathode and an anode; a capacitor having one side connected to ground and having its other side connected to said cathode of said gaseous tube; means including a resistor connecting said other side of said capacitor to said anode of said rectifier tube; a power supply source for said tube, a resistor shunted across said source, means connecting said grid and said anode of said tube to different points along said resistor; means for supplying direct current

from said tube when it conducts to said armature winding, and a direct current source of constant voltage connected to said armature winding in opposite polarity to the current from said tube, said motor being energized to rotate in one direction when the current from the said tube to said winding is greater than the current from said direct current source to said winding, and being energized to rotate in the opposite direction when the current from said tube to said winding is less than the current from said direct current source to said winding.

13. A voltage stabilizing system for a radio frequency generator including an oscillator tube having a filament, comprising a source of current for said filament; means including a reversible motor having an armature winding for adjusting the voltage of the current supplied by said source to said filament; a rectifier tube having an anode connected to receive radio frequency current from said generator, and having a cathode, a resistor connected to said cathode and to ground; a gaseous electron tube having a grid, a cathode and an anode; a capacitor having one side connected to ground and having its other side connected to said cathode of said gaseous tube; means including a resistor connecting said other side of said capacitor to said anode of said rectifier tube; a power supply source for said tube, a resistor shunted across said source; means connecting said grid and said anode of said tube to different points along said resistor; means for supplying direct current from said tube when it conducts to said armature winding, and a direct current source of constant voltage connected to said armature winding in opposite polarity to the current from said tube, said motor being energized to rotate in one direction when the current from the said tube to said winding is greater than the current from said direct current source to said winding, and being energized to rotate in the opposite direction when the current from said tube to said winding is less than the current from said direct current source to said winding.

14. In combination a thermionic oscillation generator, an electric discharge valve having principal electrodes and a control electrode, connections between said generator and said control electrode for varying the conductivity of said valve in accordance with the oscillatory voltage of said generator, and connections between said principal electrodes and said generator for varying the oscillatory voltage of said generator in dependence upon the variation of the conductivity of said valve.

15. In combination a thermionic oscillation generator, an electric discharge valve having principal electrodes and a control electrode, connections between said generator and said control electrode for varying the conductivity of said valve in accordance with the oscillatory voltage of said generator, and connections between said

principal electrodes and said generator for varying the oscillatory voltage of said generator in dependence upon the variation of the conductivity of said valve in a sense such as to tend to restoring said oscillatory voltage to a magnitude from which it varies.

16. In combination a thermionic oscillation generator including a first electric discharge valve having a cathode to be heated; a second electric discharge valve having principal electrodes and a control electrode; connections between said generator and said control electrode for varying the conductivity of said second valve in dependence upon the variation in the oscillatory voltage of said generator; and connections between said principal electrodes and said cathode for varying the temperature of said cathode in dependence upon the varying conductivity of said second valve.

17. In combination a thermionic oscillation generator including a first electric discharge valve having a cathode to be heated and an output load circuit; a second electric discharge valve having principal electrodes and a control electrode, said second valve being of the gaseous type; connections including a capacity coupling to said load circuit between said generator and said control electrode for varying the conductivity of said second valve in dependence upon the variation in the oscillatory voltage of said generator; and connections between said principal electrodes and said cathode for varying the temperature of said cathode in dependence upon the varying conductivity of said second valve.

18. In combination a thermionic oscillation generator comprising a pair of push-pull connected electric discharge devices and an output tank circuit, each of said discharge devices having a cathode to be heated, a gaseous discharge device having principal electrodes and a control electrode, connections between said output tank circuit and said control electrode for varying the conductivity of said gaseous discharge device in dependence upon the variation in the oscillatory output voltage of said generator, and connections between said principal electrodes and each of said cathodes for varying the temperature of said cathodes in dependence upon the varying conductivity of said gaseous discharge device.

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