

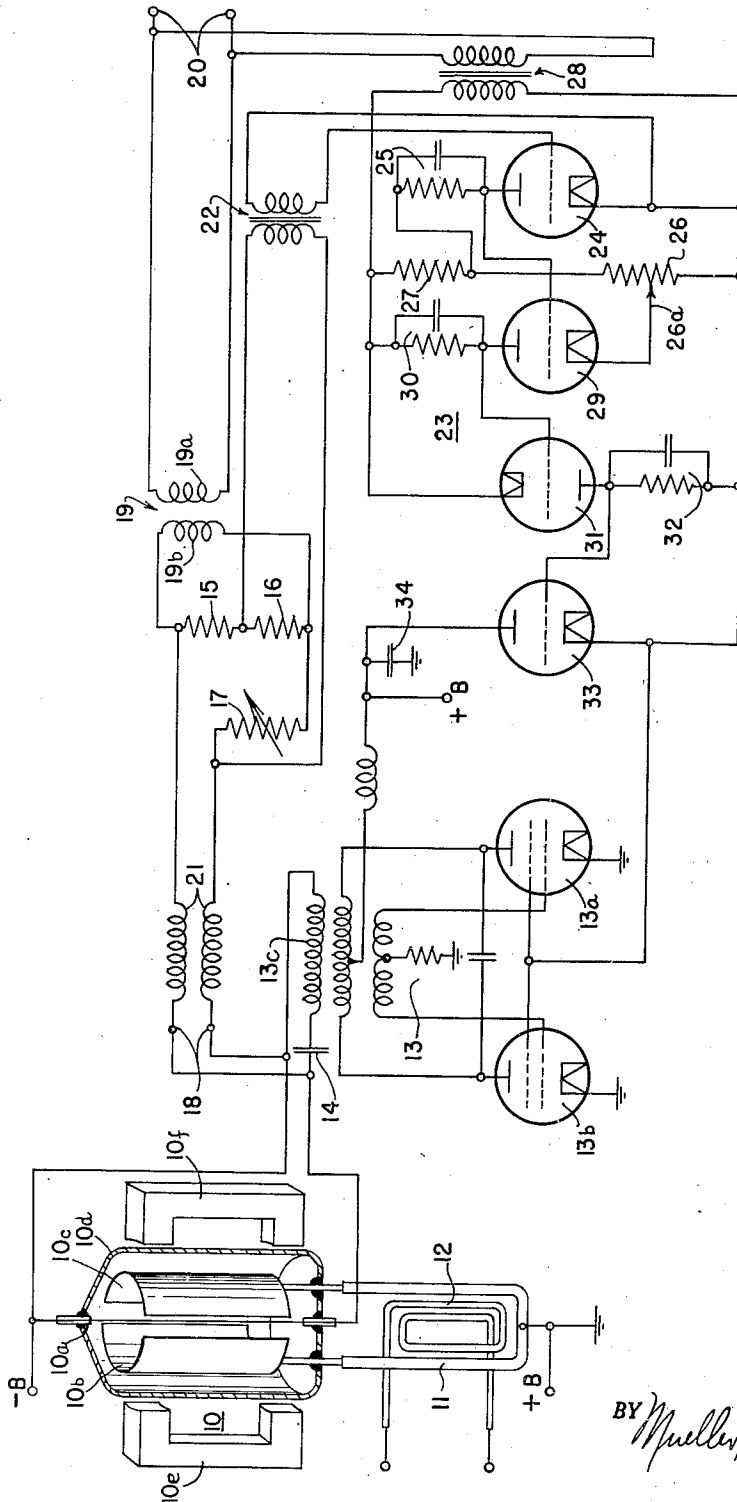
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CATHODE-TEMPERATURE CONTROL SYSTEM

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CATHODE-TEMPERATURE CONTROL SYSTEM

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This invention relates to a cathode-temperature control system and, while it is of general application, it is particularly adapted to maintain constant the temperature of a filamentary cathode of an electron-discharge device under widely varying space-current conditions.

In the case of electron-discharge devices of the directly heated cathode type, the space current of the device traverses the cathode and contributes to its heating, this effect being known as "back heating." In certain installations such heating of the filamentary cathode is sufficient under normal operating conditions so that the cathode heating supply may be disconnected after a warm-up interval. In other installations it is desirable, for maximum life of the cathode, to vary the heating current to the cathode with variations in the space-current conditions of the device in order to maintain the temperature of the cathode substantially constant. However, it is obvious that conventional current or voltage regulators for the filament-current supply circuit are ineffective to procure the desired result.

It is an object of the invention, therefore, to provide a new and improved cathode-temperature control system for an electron-discharge device of the directly heated cathode type by means of which the temperature of the cathode heating element may be maintained substantially constant under widely varying space-current conditions.

In accordance with the invention, a system for maintaining constant the temperature of the cathode-heating element of an electron-discharge device under varying space-current conditions comprises means for supplying heating current to the element, and means responsive to the resistance of the element for controlling the current-supply means to vary the heating current to the element inversely in accordance with the resistance thereof.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing while its scope will be pointed out in the appended claims.

Referring now to the drawing, the single figure is a circuit diagram, partly schematic, of a cathode-temperature control system for an electron-discharge device of the directly heated cathode type.

Referring now to the drawing, there is represented a system for maintaining constant the temperature of an electrical heating element hav-

ing a substantial temperature-coefficient of resistance, for example, a filamentary-cathode or other cathode-heating element 10a of an electron-discharge device 10 of the magnetron type, under varying space-current conditions. The magnetron 10 includes in addition to the filamentary-cathode 10a a pair of opposed semi-cylindrical anodes 10b, 10c surrounding the cathode 10a, these elements being included within a conventional evacuated glass envelope 10d. Disposed adjacent the anodes 10b and 10c and exterior of the envelope 10d are a pair of horseshoe-shaped permanent magnets 10e, 10f, respectively. Connections are made to the cathode 10a and the anodes 10b and 10c through suitable lead-in conductors sealed into the glass envelope 10d in a conventional manner. The magnetron 10 is shown as connected to function as an ultra-high-frequency oscillator and to this end there is provided a transmission line 11 of a length equal to one-quarter of the wave length of the operating frequency of the oscillator and having its open end connected directly to the lead-in conductors of the anodes 10b, 10c and having its remote end short-circuited and grounded as indicated. Space-current for operation of the magnetron oscillator is provided from a suitable source +B, which is grounded, the negative terminal of the source -B being connected to the cathode 10a as shown. The generated oscillations are derived from a pick-up coil 12 coupled to the transmission line 11. It is to be understood that the magnetron oscillator 10 schematically illustrated and described forms no part of the present invention but is included solely for illustrative purposes.

The system also includes means for supplying heating current to the cathode element 10a. This means may be in the form of a conventional push-pull oscillator 13 including a pair of tubes 13a and 13b of the screen-grid type and coupled to the cathode element 10a through an output winding 13c and a coupling condenser 14. The oscillator 13 is energized from a suitable source +B and is preferably designed to generate relatively high-frequency oscillations, for example at 6 megacycles.

The system also includes means responsive to the resistance of the cathode element 10a for controlling the current-supply oscillator 13 to vary the heating current to the cathode element 10a inversely in accordance with the resistance thereof. This control means includes a bridge circuit comprising two parallel branches, one including series-connected resistors 15 and 16 and the other including an adjustable resistor 17 and

connection terminals 18 for including the cathode element 10a as an arm of the bridge in series with the adjustable resistor 17. There are provided means for energizing the bridge circuit at a level such as to have an inappreciable effect on the temperature of the cathode element 10a. This means may consist of a transformer 19 having a primary winding 19a connected to supply terminals 20, which may be ordinarily commercial 60-cycle alternating-current lines. The secondary winding 19b of the transformer 19 is designed to deliver an output voltage preferably of the order of 1 volt and this is applied to the two branches of the bridge circuit in parallel. With this arrangement, the frequency of the energization of the bridge circuit, that is the 60-cycle energization, is substantially different than that of the current-supply oscillator 13, that is the 6 megacycle oscillations, so that there may be readily provided impedance means for effectively isolating the current-supply means and the bridge circuit energizing means from each other. This impedance means comprises a pair of radio-frequency choke coils 21 individually included in series with the connection terminals 18 for suppressing the high-frequency oscillations from the bridge circuit and a series coupling condenser 14 in series with the oscillator output winding 13c and of such a value as substantially to suppress 60-cycle energy from the oscillator 13.

The means for controlling the oscillator 13 also includes means responsive to the unbalance of the bridge circuit for varying the output of the oscillator 13. Specifically, the unbalance voltage of the bridge circuit is applied through a coupling transformer 22 to the input circuit of a 3-stage direct-current amplifier 23. Specifically, the bridge unbalance voltage is applied to the signal-input grid of a first tube 24 having an anode load circuit 25 and connected across a resistor 26 of a voltage divider comprising the resistor 26 and a resistor 27. The resistors 26 and 27 are connected across a suitable source of space-current, for example the secondary winding of a supply transformer 28 the primary winding of which is connected to the supply terminals 20.

The output circuit 25 of tube 24 is connected to the signal-input electrode of the succeeding amplifier tube 29, the cathode of which is connected to an adjustable contact 26a of the resistor 26 in order to provide a proper bias for its grid. The anode of the tube 29 is connected to the supply source through a suitable load circuit 30. The load circuit 30 of tube 29 is connected directly to the grid of a third vacuum-tube amplifier 31 connected with reverse polarity across the secondary winding of transformer 28 and provided with a load circuit 32. It is noted that the source of space current for each of the vacuum tube of amplifier 23 is low alternating-current. However, the parallel connected resistor and condenser comprising the load circuit of each of the tubes 24, 29 and 31 is designed to have such a time constant that each of the tubes operates effectively as a rectifier and also serves to provide a source of substantially continuous bias for the signal-input grid of the next succeeding amplifier tube, there being developed across the load circuit 32 of the final amplifier tube 31 a unidirectional bias voltage varying with the unbalance of the bridge circuit.

The control system for the heating-current oscillator 13 also includes means for utilizing the bias voltage developed as described to vary the heating current to the cathode element 10a. This

means may comprise a variable-impedance vacuum tube 33 having its control electrode connected directly to the load circuit 32 and having its anode-cathode circuit connected in series between the source +B and the screen-grid circuit of the vacuum tubes 13a and 13b of the oscillator 13. The source +B is provided with a suitable by-pass condenser 34.

The operation of the cathode-temperature control system will be apparent from the foregoing description. In brief, the magnetron oscillator 10 operates in a conventional manner to generate ultra-high-frequency oscillations of a frequency determined by the transmission line 11 which is of a physical length one-quarter that of the wavelength of the generated oscillations. Such generated oscillations are picked up by the winding 12 and supplied to any suitable utilization circuit. After the oscillator 10 has been operating for a sufficient time to reach a condition of equilibrium, a considerable portion of the energy derived from the space current source +B is consumed in the cathode-heating element 10a, thereby considerably raising the temperature of the cathode. This is known as "back heating" and tends to shorten the life of the magnetron or, in extreme cases, to burn out the cathode element 10a. As stated above, a simple regulation of the cathode-heating current or voltage is ineffective to compensate for this effect. When the magnetron oscillator 10 is operating normally, it may be even possible to reduce to zero the cathode-heating current.

To this end, the resistance of the cathode-heating element 10a, which is a measure of its temperature due to its high positive temperature-coefficient of resistance, is included in the bridge circuit comprising the resistors 15, 16 and 17 and the resistor 17 is then adjusted to a value corresponding to an appropriate temperature of cathode-heating element 10a. Should the temperature of the cathode-heating element 10a thereafter tend to rise further, due to any cause, its resistance increases correspondingly, the bridge circuit is unbalanced and the unbalance voltage is applied to the input grid of the first-stage amplifier tube 24. It will be assumed that under these conditions the alternating unbalanced potential derived from the bridge circuit is in phase with the alternating anode potential of the vacuum tube 24, so that the space current of the tube is increased over that due to its steady-state bias which, as illustrated, may be zero. The amplified and rectified unbalance potential of the bridge circuit appears across the load circuit 25 and is applied as a bias to the succeeding amplifier tube 29, which develops a further amplified unidirectional bias across its load circuit 30. Further, the bias across the load circuit 30 is applied directly to the grid of the final vacuum tube amplifier 31 which develops a negative bias potential across its load circuit 32 for application to the control grid of the variable-impedance tube 33. The increasing negative bias on this tube increases its impedance, thereby lowering the screen potential of the oscillator tubes 13a and 13b to decrease the amplitude of the high-frequency oscillations generated by the oscillator 13 and thereby decrease the heating current to the cathode 10a to restore its temperature to normal.

Obviously, when the temperature of the cathode 10a drops for any cause, the reverse process takes place; that is the unbalance potential of the bridge circuit is applied to the grid of the

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tube 24 in phase opposition with its anode potential, thereby decreasing the bias potential developed across its load circuit 25 and decreasing the negative bias applied to the variable-impedance tube 33 to increase the screen potential of the oscillator tubes 13a and 13b, thereby to increase the amplitude of the generated oscillations and the heating current supplied the cathode element 10a.

It will be noted that the first two stages of the amplifier 23 comprise a conventional direct-current amplifier, the anode and cathode potentials of the second stage tube 29 being raised above those of the first stage tube 24 in order to provide an appropriate unidirectional bias on the grid of the second tube 29. The third tube 31, however, is connected across the supply circuit with reverse polarity so that the bias potential developed across the load circuit 30 may be applied directly to the input grid thereof. The amplifier 23 may by this manner be constructed with as many stages as desired, all operating at substantially the full supply voltage, by reversing the polarity of connection of the tubes of alternate stages, as illustrated with respect to the second and final stages of amplifier 23.

It is seen that the system described is a closed regenerative one. As the sensitivity and time delay of the amplifier 23 are increased the system will go into continuous oscillation. For somewhat lower values of sensitivity and time delay the oscillations are damped, dying out after a few cycles and resulting in what is known as hunting. A further reduction in the values of sensitivity and time delay of the amplifier 23 is effective to make the system non-oscillating and to maintain a steady-state condition, although in this last case the operation of the system is somewhat sluggish; that is, it does not respond rapidly to sudden variations in operating conditions.

While the circuit constants of the temperature-control system of the invention may be varied within wide limits in accordance with operating conditions, there follow the circuit constants of a particular system for controlling the cathode temperature of a magnetron oscillator:

Oscillator tubes 13a, 13b	Type 829
Magnetron cathode	
(35 watts)	1.6 ohms
Resistor 15	10 ohms
Resistor 16	10 ohms
Resistor 17	0-3 ohms
Winding 19b	1 volt
Tubes 24 and 29	Type 6SN7 (duplex)
Tube 31	Type 6SF5
Tube 33	Type 6J4
Resistor 26	10 kilohms
Resistor 27	40 kilohms
Load circuits 25, 30 and 32:	
Resistance	1 megohm
Capacitance	0.1 microfarad

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit or scope of the invention.

What is claimed as new is:

1. A system for maintaining constant the temperature of the cathode heating element of an electron-discharge device under varying space-current conditions comprising, a high-frequency oscillator for supplying heating current to said

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element, and means responsive to the resistance of said element for controlling said oscillator to vary the heating current to said element inversely in accordance with the resistance thereof, said last-mentioned means including a low frequency variable energy source for furnishing an output depending upon the value of said resistance.

2. A system for maintaining constant the temperature of the cathode heating element of an electron-discharge device under varying space-current conditions comprising, a high-frequency screen-grid-tube oscillator for supplying heating current to said element, a variable impedance tube in series with the screen-grid circuit of said oscillator, and means responsive to the resistance of said element for controlling said tube to vary the heating current to said element inversely in accordance with the resistance thereof.

3. A system for maintaining constant the temperature of the cathode heating element of an electron-discharge device under varying space-current conditions comprising, means for supplying heating current to said element, a bridge circuit having connections for including said element as an arm thereof, means for energizing said bridge circuit at a frequency substantially different than that of said current-supply means, impedance means for effectively isolating said current-supply means and said energizing means, and means responsive to the unbalance of said bridge circuit for controlling said current-supply means to vary the heating current to said element inversely in accordance with the resistance thereof.

4. A system for maintaining constant the temperature of an electrical heating element having a substantial temperature-coefficient of resistance comprising, means for supplying heating current to said element, a bridge circuit having connections for including said element as an arm thereof, means for energizing said bridge circuit at a frequency substantially different than that of said current-supply means, impedance means for effectively isolating said current-supply means and said energizing means, and means responsive to the unbalance of said bridge circuit for controlling said current-supply means to vary the heating current to said element inversely in accordance with the resistance thereof.

5. A system for maintaining constant the temperature of the cathode heating element of an electron-discharge device under varying space-current conditions comprising, controllable means for supplying heating current to said element, a bridge circuit having connections for including said element as an arm thereof, a source of electrical energy different from said current-supply means arranged to energize said bridge circuit without producing appreciable heating of said element, said bridge circuit including reactive means permitting the flow of current from said energy source through said bridge circuit but excluding the heating current from all arms of said bridge circuit except that containing said element, and electrical means including a variable impedance element responsive to the unbalance of said bridge circuit for controlling said current-supply means to vary the heating current to said element inversely in accordance with the resistance thereof.

6. A system for maintaining constant the temperature of the cathode heating element of an electron-discharge device under varying space-current conditions comprising, controllable means including a high frequency oscillator for supply-

ing heating current to said element, a bridge circuit having connections for including said element as an arm thereof, a low frequency low voltage source of electrical energy arranged to energize said bridge circuit without producing appreciable heating of said element, said bridge circuit including reactive means permitting the flow of current from said energy source through said bridge circuit but excluding the heating current from all arms of said bridge circuit except that containing said element, and electronic means including a reactance tube responsive to the unbalance of said bridge circuit for controlling said oscillator to vary the heating current to said ele-

ment inversely in accordance with the resistance thereof.

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