

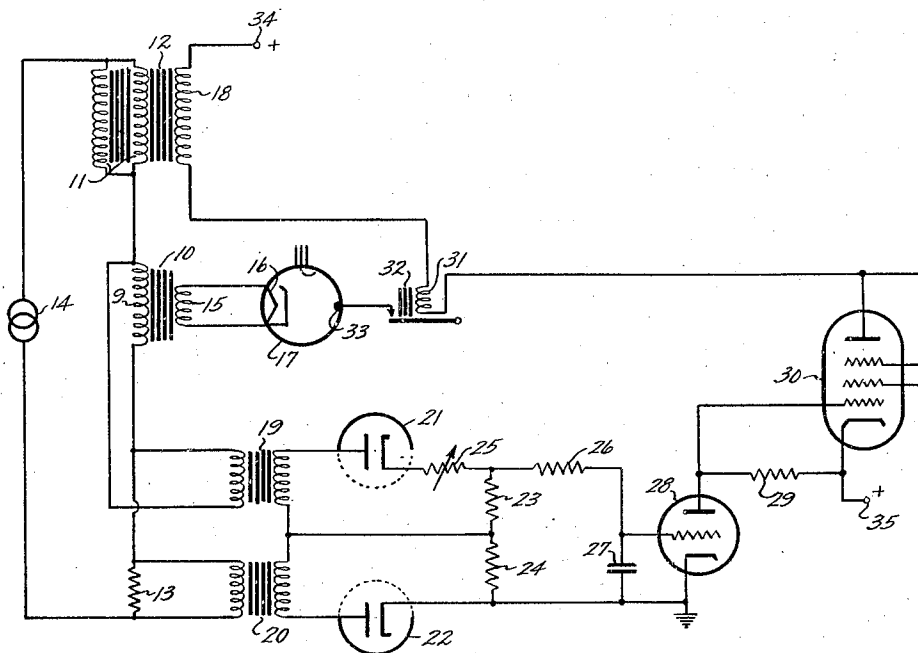
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MAGNETRON FILAMENT TEMPERATURE REGULATOR

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MAGNETRON FILAMENT TEMPERATURE
REGULATOR

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The invention described herein may be manufactured and used by or for the Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to vacuum tube apparatus and particularly pertains to the regulation of magnetron filament temperatures.

In certain applications, the plate voltage of magnetron tubes must be interrupted frequently in which case it becomes necessary to lower the filament voltage each time plate voltage is applied, due to the backheating which is caused by bombardment of electrons that do not go to the plate but return to the filament and bombard the latter with sufficient force to cause excessive heating thereof. Consequently, it is particularly desirable to provide a means for the automatic regulation of filament voltage so as to insure a constant filament temperature.

It is an object of this invention, therefore, to provide a method of controlling the operating filament temperature of vacuum tubes by utilizing the variation in the ratio of filament current to filament voltage produced by changes in filament temperature.

It is a further object of this invention to provide a method of controlling the operating filament temperature of vacuum tubes, by detecting and measuring the variation in the ratio of filament current to filament voltage, and utilizing such measured variation to control the filament temperature by readjustment of the filament voltage.

A further object of this invention is to provide means for automatically regulating the voltage of a vacuum tube filament so as to maintain the filament at a constant temperature.

As still further object of this invention is to provide a means for detecting variations in filament current with respect to filament voltage, and for utilizing these variations to control the voltage drop across the filament.

Other objects and features of this invention will become apparent when the following description is read in connection with the annexed drawing in which is shown a schematic diagram of a preferred embodiment of my invention.

According to my invention generally, it is proposed to connect, in series with a magnetron filament transformer, a variable (saturable) reactor whose secondary winding may be controlled by a means responsive to filament current fluctuations, so as to reduce the voltage on the filament transformer when backheating occurs.

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In the drawing, the primary winding 9 of the filament transformer 10 is connected in series with the A. C. windings 11 of a variable reactor 12 and a fixed resistor 13, across an A. C. power source 14. The frequency of the A. C. power source may be between 400 and 1600 cycles in the case of aircraft systems or 60 cycles in ground installations. The filament transformer secondary winding 15 is connected to the filament 16 of magnetron 17. The voltage drop appearing across A. C. winding 11 will vary depending upon the amount of current flowing through the D. C. winding 18 of the saturable reactor 12. The voltage drop across the filament transformer primary winding 9 will vary inversely with the voltage drop across winding 11, provided, of course, resistor 13 is of relatively low resistance.

It will now be explained how a differential change in the ratio of filament voltage to filament current, after being applied to a balanced detector circuit, operates to control the bias of a vacuum tube whose output current flows through the D. C. (control) winding of the variable reactor.

Since the resistance of a tungsten filament varies directly with the temperature rise of the filament over the operating range, then temperature changes can be determined by measuring and comparing the voltage and current required to heat the filament. The secondary of a filament transformer is usually at a high negative D. C. potential, and it is therefore more practical to measure the current and voltage in the primary since the voltage and current in the primary of a transformer is directly proportional to the voltage and current in the secondary.

According to my invention, a transformer 19 for measuring voltage is connected in parallel with the magnetron filament transformer. A transformer 20 for measuring current may be connected, either in series with the filament transformer, or it may be connected across a resistor which is in series with the filament transformer. The latter arrangement is shown in the drawing and is considered to be the more desirable arrangement for the following reasons: When measuring current through a circuit, it is customary to use a transformer having a few turns on the primary and many turns on the secondary provided a constant frequency power source is used. However, because the secondary voltage of a transformer is a function of frequency as well as the current in the primary, when a variable frequency power source is used,

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it becomes preferable to use a low resistance in series with the primary of the magnetron filament transformer, and to measure the voltage drop across the resistor. Such a resistor, however, in addition to having a flat frequency response, should have a substantially zero temperature coefficient since varying currents through the resistor would otherwise cause its resistance to vary.

Experiment has shown that peak values of magnetron filament current and voltage do not vary uniformly because of harmonic distortion and leakage inductance in reactor 12. On the other hand, it has also been found that the actual R. M. S. values of voltage and current do vary uniformly. Therefore, it is desirable to measure the R. M. S. value of voltage and current or preferably to use average reading detectors, since the average values of voltage and current are more easily measured and closely follow R. M. S. values. Average reading detectors have proportionately lower voltage outputs than have peak reading detectors, consequently some amplification of the control voltage is usually necessary in order to meet control range requirements.

Referring again to the drawing, the secondary windings of transformers 19 and 20 are connected to the plates of diodes 21 and 22 respectively. Two resistors 23 and 24 of equal size are connected across the cathodes of diodes 21 and 22 respectively, and the midpoint of said resistors is tied to a connection between the secondaries of transformers 19 and 20 as shown. In operation, D. C. output voltages will exist across resistors 23 and 24, which follow variations in magnetron filament voltage and current respectively. The algebraic sum of the voltages across resistors 23 and 24 will produce a reference voltage which will be the difference between the two D. C. output voltages.

A variable resistor 25 is inserted in the output from tube 21 simply for the purpose of adjusting the relative outputs from the two diodes during initial setting of the filament voltage.

Resistor 26 in conjunction with condenser 27 forms a filter section for deriving an average filtered reference voltage which can be applied to the grid of tube 28. The cathodes of tube 28 and diode 22 are connected together and to ground. Tube 28 serves to amplify the reference voltage. A plate load resistor 29 connecting the plate of tube 28 to the cathode of amplifying tube 30 is supplied with a low positive D. C. voltage 35. The plate of tube 28 is directly coupled to the grid of tube 30. The D. C. plate voltage to tube 30 is supplied from a source of positive D. C. voltage 34 through a series circuit comprising the reactor winding 18 and the operating coil 31 of a relay 32. This relay interrupts the voltage to the magnetron anode 33 when the filament voltage drops to approximately $\frac{1}{3}$ of its normal value, or when the current output from tube 30 drops below the lower limit of regulation.

In operation, resistor 25 should be adjusted so that the magnetron filament has the correct voltage on it with no plate voltage applied. Tube 28 is biased at cut-off but no bias is placed on tube 30 since no voltage drop exists across resistor 29. Tube 30 conducts heavily creating a relatively low A. C. voltage drop across the primary winding of reactor 12 and a relatively high voltage across filament transformer 10. When the intermittent magnetron plate voltage is applied, backheating occurs and the filament re-

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sistance increases, lowering the filament current, causing a lower voltage drop across resistor 13 and a lower voltage across transformer 20. The output from diode 22 becomes less, so that the sum of the output of diodes 21 and 22 becomes relatively more positive. The resulting decrease in the bias on the grid of tube 28 causes the tube to draw current and thus produce a voltage drop across resistor 29. The negative bias thus created on the grid of tube 30 causes the current through the D. C. winding 18 of reactor 12 to be reduced. This increases the A. C. voltage drop across the primary winding of transformer 12 and lowers the voltage across the filament transformer. The voltage across the magnetron filament is thus decreased until the combined effect of the filament power and the backheating is sufficient to maintain the filament at a constant temperature. Thus, the circuit automatically accommodates itself to fluctuations in filament temperatures. I have found that only a slight increase in temperature (and filament resistance) is required to maintain the circuit at its new condition.

While I have described and illustrated a preferred embodiment of my invention, it will be apparent to those skilled in the art, that many variations and changes may be made therein, without departing from the spirit of the invention or its scope as defined in the appended claims.

I claim:

1. A method of regulating the temperature of a vacuum tube filament, which consists in inductively detecting a variation in the ratio of filament current with respect to filament voltage, measuring the value of said variation separately in both voltage and current, and utilizing said measured value to provide a reference voltage used to adjust the filament voltage to the value necessary for restoring the filament temperature to normal.

2. A method of controlling the temperature of a vacuum tube filament, which consists in obtaining an A. C. voltage proportional to the current drawn by the filament, obtaining an A. C. voltage proportional to the voltage across the filament, converting said A. C. voltages into D. C. voltages, differentially combining said D. C. voltages so as to produce a reference voltage, and utilizing said reference voltage to adjust the filament voltage to maintain the filament temperature constant.

3. A method of controlling the temperature of a vacuum tube filament, which consists in deriving a pair of A. C. voltages which are respectively proportional to the current drawn by the filament and to the voltage across the filament, converting said A. C. voltages into D. C. voltages, differentially combining said D. C. voltages so as to produce a reference voltage, amplifying said reference voltage, and utilizing said amplified voltage to control the filament voltage to maintain the filament temperature constant.

4. In apparatus for regulating the temperature of an electrically heated vacuum tube filament comprising an A. C. power source, a variable impedance element, a vacuum tube filament heating filament transformer secondary winding having its opposite ends connected to the ends of said filament but otherwise insulated and coupled with a primary winding connected in series with said element to said power source, inductive means distinguishing current variations from voltage variations for detecting filament temperature variations, and means connected with said de-

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tor means for controlling the impedance of said variable impedance element in response to changes in filament temperature.

5. In apparatus for regulating the temperature of a vacuum tube filament, an A. C. power source, filament transformer means for supplying inductively said filament with current and voltage from said source, a saturable reactor having a primary winding and a secondary winding, said primary winding being serially connected between said source and said transformer means, means distinguishing current from voltage for deriving a filtered reference voltage which varies in accordance with variations in the temperature of said filament, means for converting said reference voltage into corresponding current variations, and circuit means for passing said current variations through the secondary winding of said saturable reactor so as to produce corresponding variations in the voltage drop across said primary winding, thereby varying the potential across said transformer means.

6. The invention recited in claim 5 including a plate voltage source, a vacuum tube, an anode within said vacuum tube, means for connecting said anode with said plate voltage source, and means controlled by the amount of current flowing in said circuit means for disabling said connecting means.

7. In apparatus for regulating the temperature of a vacuum tube filament, an A. C. source of power, transformer means for supplying the filament with current and voltage from said source of power, saturable reactor means comprising a primary winding and a secondary winding, said primary winding being serially connected between said source of power and said transformer means, means for deriving a pair of A. C. voltages respectively proportional to the voltage and current in said filament, means for rectifying each voltage of said pair to produce two pulsating D. C. output voltages, means for adjusting the relative value of said pulsating D. C. output voltages, means for combining said two pulsating D. C. output voltages to produce a difference voltage output, means for deriving from said difference voltage output an average filtered reference volt-

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age, means for amplifying said reference voltage so as to produce a current which varies in accordance with variations in said reference voltage, circuit means for passing the current produced by said amplifying means through said secondary winding of said reactor means whereby variations in said reference voltage produce corresponding variations in the voltage of said primary winding of said reactor means and consequently in the filament voltage so as to effect corresponding changes in the temperature of said filament.

8. In combination with a magnetron having a filament and an anode, an alternating current circuit supplying inductively heat energy to said filament, a saturable reactor having a pair of alternating current windings connected in parallel in the alternating current circuit and a direct current control winding connected to a direct current power source supplying a direct current circuit coupled inductively with the reactor alternating current windings and wherein the alternating current windings are responsive to the magnitude of current flow in the direct current winding, an amplifying vacuum tube in the direct current circuit and applying its output to the reactor direct current control winding through a relay operating coil interrupting the voltage to the magnetron anode when the current output of said amplifying vacuum tube becomes outside predetermined limits of regulation, and a detector circuit balanced separately for voltage and current to control the heat energy supplied to the magnetron filament by controlling the bias applied to the amplifying vacuum tube.

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