

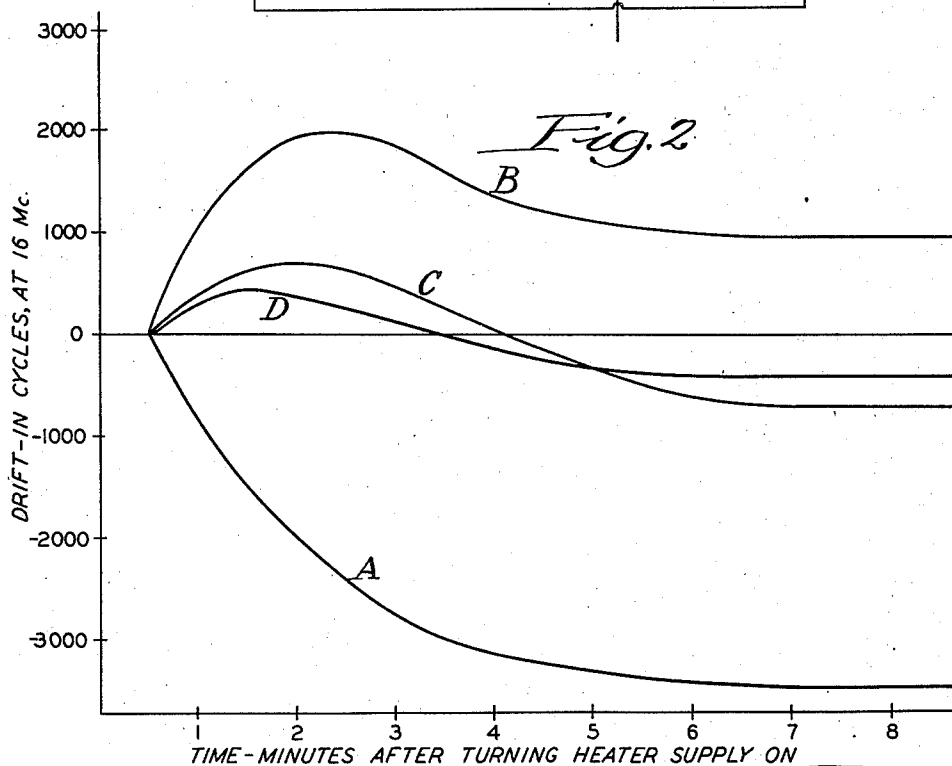
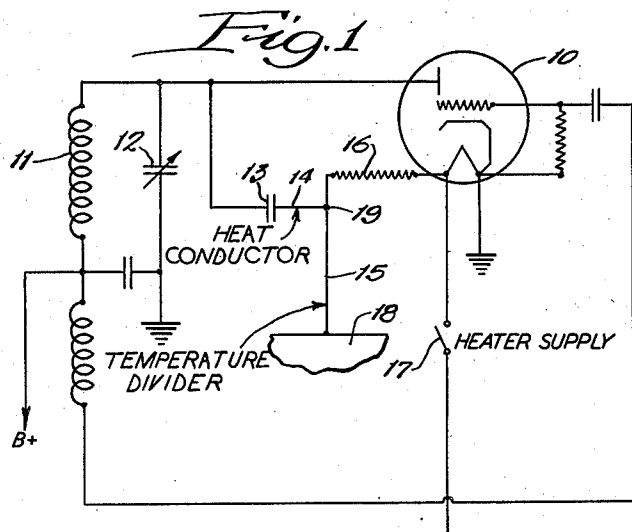
March 20, 1945.

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2,371,790

TEMPERATURE COMPENSATED TUNED CIRCUIT

Filed Aug. 17, 1942



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UNITED STATES PATENT OFFICE

2,371,790

TEMPERATURE COMPENSATED TUNED
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Application August 17, 1942, Serial No. 455,140

24 Claims. (Cl. 250—36)

This invention relates to temperature compensated tuned circuits and has for its principal object to provide an improved temperature compensated tuned circuit.

The invention is particularly adapted for use in connection with oscillators and will be described in connection with an oscillator. It will, however, be understood that the invention is applicable to any tuned circuit associated with the operating circuit of a thermionic tube.

When an oscillator tube is heated up, the frequency of the associated tuned circuit drifts, becoming lower, if the tuned circuit includes inductance and capacity of usual form. This drift may be divided into two parts, one part consisting of frequency changes resulting from changes of parameters and characteristics of the elements of the tube as a result of its heating up. This part of the drift occurs during an appreciable time period in the case of tubes having indirectly heated cathodes.

When a tube heats up, there is capacity change between any two of its electrodes because of change in at least three factors. As the tube heats up, its structural portions change size and the spacing between the electrodes changes, resulting in a change of inter-electrode capacity. When the dielectric structure within the tube changes, the dielectric constant of the dielectric material changes to some extent and is associated with a change in capacity between electrode connections. As the tube heats up, its cathode emission increases, resulting in an increase in electron density between electrodes and a corresponding change in interelectrode capacity by reason of this changed electron density between electrodes.

The other part of the drift consists of frequency changes resulting from heating up the other parts of the tuned circuit, for example, the capacitor and the inductor. The latter part of the drift depends upon the ambient temperature.

The first part which normally causes most of the drift, occupies about five or ten minutes, depending upon the type of tube used. The other part of the drift may be detected for a much longer period, for example 45 or 60 minutes. The first part corresponds to the heating up of the tube and the other part corresponds to the heating up of the set as a whole and particularly corresponds to the time necessary for the capacitor and the inductor of the tuned circuit to attain static temperature conditions. For convenience I refer to the first part of the drift as the initial

drift and the other part of the drift as the long term drift.

In the broadcast range, the drift is small enough to be negligible. However, with high frequency oscillators, for example, oscillators having a frequency of the order of 15 megacycles, the drift referred to becomes a very serious objection.

One of the objects of the invention is to provide a simple means for correcting both initial and long term drift of a tuned circuit.

A further object of the invention is to provide an improved tuned circuit associated with a thermionic tube which will hold its operating frequency within very close limits from the initiation of and throughout its operation.

A further object of the invention is to provide an improved tuned circuit in which a combination of a single heater and a compensating condenser is arranged to correct both initial and long term drift.

A further object is to provide an improved tuned circuit compensated for both initial and long term drift and having substantially constant frequency over a wide range of heater supply voltage.

Other objects, advantages and capabilities of the invention will appear from the following description of a preferred embodiment taken in conjunction with the accompanying drawing, in which:

Fig. 1 is a wiring diagram of an oscillator embodying my invention; and

Fig. 2 is a set of curves showing the drift of an oscillator with respect to time for various adjustments of the compensating elements.

Referring to the drawing, the reference numeral 10 designates a thermionic tube. The tuned circuit inductance is designated 11 and the tuning capacitance is provided by two capacitors 12 and 13. A single capacitor may be employed instead of the two capacitors 12 and 13 but for reasons which will hereinafter appear, I prefer to employ two capacitors in this relation.

The two capacitors 12 and 13 have together an effective capacity coefficient which compensates the circuit for changes in the ambient temperature. In order to provide this correction, it is necessary to determine the residual (C_0) capacity of the tuned circuit, that is, the capacity other than that provided by the capacitors 12 and 13.

To determine the residual capacity, I remove the capacitor 13 and replace the capacitor 12 by a capacitor of known value (C_1) and determine the oscillator frequency (F_1). I repeat the test with a different known capacitor (C_2) and

again determine the frequency (F_2). The residual capacity is known from the equation:

$$C_0 = \frac{F_2^2 C_2 - F_1^2 C_1}{F_1^2 - F_2^2}$$

Then I substitute for the capacitors 12 and 13 a capacitor having a capacity C_3 (μfarads) equal to the sum of the capacities of 12 and 13, this capacitor having a known temperature coefficient of K_3 μfarads per μfarad per degree centigrade. The temperature coefficient is considered negative when increase of temperature causes a decrease of capacity. I make two frequency determinations at two different ambient temperatures, allowing sufficient time for the set to attain constant temperatures in both cases. From the two frequency determinations I find the circuit thus constituted has a drift of df cycles per degree centigrade. " df " is considered to be positive if an increase of temperature produces an increase of frequency, and negative if an increase of temperature produces a decrease of frequency.

This drift would be compensated by increasing the capacity

$$C_0 + C_3 \text{ by } \frac{2df(C_0 + C_3)}{f}$$

per degree centigrade temperature rise. Both capacities are expressed in μfarads . If, as in most cases, df is negative, the capacity $C_0 + C_3$ is actually reduced. Since the capacitor C_3 increases the total capacity by $C_3 K_3$ per degree centigrade temperature rise, the total increase of capacity (μfarads) per degree centigrade necessary for correction for ambient temperature is

$$\frac{2df(C_0 + C_3)}{f} + C_3 K_3$$

All terms of this expression are known.

I may employ a single capacitor C_3 having a temperature coefficient K_x such that $C_3 K_x$ is equal to the last expression and have the circuit compensated for ambient temperature. I prefer, however, to use two capacitors 12 and 13, the sum of the capacities C_{12} and C_{13} being equal to C_3 and having temperature coefficients K_{12} and K_{13} respectively so that

$$C_3 K_x = C_{12} K_{12} + C_{13} K_{13}$$

Thus if I find that $C_3 K_x$ should be equal to -0.0133 μfarad per degree centigrade temperature rise where C_3 is 100 μfarads , I may use as capacitor 12 a ceramic capacitor having a capacity of 60 μfarads and a coefficient of -0.00155 μfarad per μfarad per degree centigrade, and I may use as capacitor 13 a ceramic capacitor having a capacity of 40 μfarads and having a coefficient of -0.0011 and thus have correct capacity and correct compensation for ambient temperature. The temperature coefficient of the capacitor 13 may be selected at any value suitable for correction of initial drift and the temperature coefficient of the capacitor 12 may be selected to give the necessary change of capacity for correction for ambient temperature. Usually $C_3 K_x$ is negative, but in some cases it is positive. In the latter case, K_{12} should be positive and the relation of the last equation should be preserved. The initial drift is ordinarily negative and K_{13} is correspondingly negative.

One side of each of the capacitors 12 and 13 is connected to the plate of the tube 10. The other side of the capacitor 12 is grounded to the chassis. The other side of the capacitor 13 has its lead 14 connected at a point 19 to the lead 15 of a resistor 16. The lead 15 is soldered to the chassis

18 and the resistor 16 is connected in parallel with the heater of the tube 10 so that both the heater and the resistor 16 start to heat up together when the switch 17 is closed. The lead 15 is preferably much larger than the lead 14. While, of course, it will be understood that I may employ conductors 14 and 15 other than those provided by the leads of the ceramic capacitor 13 and the heater 16, I prefer to employ the leads with which these elements are normally provided, since these devices can readily be obtained with the lead of the resistor substantially larger than the lead of the ceramic capacitor.

The conductor 15 is arranged so that it serves as a temperature divider, that is, it is a heat conductor analogous to the slide wire of a voltage divider, temperature being regarded as analogous to voltage. In other words, I provide for a temperature gradient along the conductor 15. At its upper end (as shown in the drawing) the temperature of the conductor 15 is at a maximum. At its lower end the temperature is substantially that of the chassis 18. The chassis provides a considerable mass of material so that it maintains the lower end of the conductor 15 substantially at chassis temperature, which is substantially ambient temperature. Intermediate points of the conductor 15 have intermediate temperatures which increase from the lower to the upper end, as viewed in the drawing. The position of the point of connection 19 on the conductor 15 determines the maximum temperature which the capacitor 13 attains, and the length of the relatively small conductor 14 determines primarily the rate at which the capacitor 13 heats up when the switch 17 is closed.

When the switch 17 is closed, the cathode of the tube 10 warms up almost immediately and in a matter of five or ten minutes the elements of the tube 10 have reached static temperature conditions. The resistor 16 likewise heats up almost as quickly as the cathode. There is a slight lag due to the heat capacity of the material of the conductor 15, but this lag is so small compared with the length of time required for the elements of the tube 10 to acquire their static temperatures, that it may be neglected altogether. Thus, immediately the switch 17 is closed, the point 19 of the conductor 15 heats up rather quickly but its static temperature is determined primarily by its location between the chassis 18 and the heater 16. The lead 14, being relatively small, has a definitely limited heat transfer capacity, and since the compensating capacitor 13 has an appreciable mass and moreover is subject to loss of heat through its other conductor, there is a certain time lag in the heating up of the capacitor 13 to its static condition. This lag corresponds to the lag of the temperature rise in the elements of the tube 10. The lag may be adjusted by changing the material of the conductor 14 or its cross-sectional area. I prefer, however, to adjust this lag by adjusting the effective length of the conductor 14. Just as a long piece of resistor wire has a high resistance, so a relatively long conductor 14 has a high thermal resistance and will transfer heat more slowly than would a short conductor. Thus, the length of the lead 14 is correlated to the time lag of the heating of the elements of the tube 10 after the switch 17 is closed. It is to be noted that the conductors 14 and 15 have completely negligible electrical resistances.

The final temperature which the capacitor 13

will attain, depends primarily upon the position of the point 19 on the conductor 15. If the point 19 is high (as viewed in the drawing), the ultimate temperature of the capacitor 13 is greater, and vice-versa. Movement of the point 19 upwardly or downwardly has a slight effect upon the rate of heating of the capacitor 13, but its effect is very slight and can normally be corrected by a very slight change of the length of the conductor 14.

The invention will more readily be understood by the following specific example of an oscillator embodying my invention. The heater voltage is 6 volts. The resistor 16 has a resistance of 19 ohms. The conductor 15 is a No. 16 wire approximately one inch long. The length of the conductor 14 which is a No. 22 wire, is approximately one-half inch, and it is connected to the conductor 15 at a point approximately $\frac{3}{8}$ " from the heater 16.

While the correct position of the point 19 and the correct length of the conductor 14 may be determined precisely by calculation on the basis of the thermal capacity of the capacitor 13, its radiation and conductive losses, its heat capacity, etc., it is far more convenient in practice to determine the length of the conductor 14 and the position of the point 19 experimentally in the first instance. To operate in this manner, I connect the lead 14 to a point 19 on the lead 15 and determine the initial drift when the switch 17 is closed. Since the circuit has been compensated for ambient temperature variations, the drift, if any, is due exclusively to changes in the tube 10 as a result of its increase of temperature due to the heater.

In Fig. 2 curve A shows the drift in cycles of an oscillator tuned to 16 megacycles and compensated for ambient temperature changes but not compensated for initial drift. It is to be noted that in the first six minutes, the frequency drifts lower until a total drift of about 3500 cycles is attained, whereafter the frequency remains substantially constant.

With the circuit of Fig. 1, I may obtain a curve of the general type shown in curve B. It is here to be noted that in the first couple of minutes the frequency increases rapidly and then drops rapidly until at the end of about six minutes, the frequency becomes relatively constant. The drift of two minutes which may amount to about 2000 cycles, indicates that the capacitor 13 heats up too rapidly, whereas the final drift of 1000 cycles indicates that the final temperature of the capacitor 13 is too high. To correct the curve B, I do two things: First I move the point 19 downwardly away from the heater 16 and I lengthen the conductor 14. The first adjustment brings the final part of the curve downwardly in the manner shown in curve C and the other adjustment reduces the initial hump on the curve. The low final frequency of curve C indicates that the final temperature is too low and I move the point 19 upwardly. At the same time I reduce the initial hump on curve C by lengthening conductor 14 to a slight extent. I thus obtain curve D which corresponds to excellent compensation since the drift is less than 500 cycles in 16,000,000. I may, however, greatly improve the curve D by continued small manipulations of the position of the point 19 and the length of the conductor 14. Curve D is, however, regarded as indicating perfect compensation for all practical purposes. Compensation of the nature of curve

D enables an oscillator to be turned on and utilized immediately the cathode warms up to give immediate reception or transmission with drift so small as to be completely negligible.

While I prefer to determine the correct position of the point 19 and the length of the conductor 14 in this manner, it must be understood that when I have determined these two parameters in prototype sample, I may employ these same parameters in the assembly of any number of circuits using elements of the same characteristics. While there may be a slight variation in the curve D for oscillators thus fabricated due to slight variations in the parameters of the tubes, the heater 16 and the capacitor 13, these variations tend to cancel each other in most cases and those cases which are not compensated to sufficient degree of accuracy, can readily be found by test and corrected by slight change of position of the point 19 and/or a slight variation in the length of the conductor 14.

One remarkable attribute of my improved tuned circuit is that it has a very slight variation of frequency with change of heater supply voltage. Thus, with an oscillator tuned and compensated for a frequency of 16 megacycles in accordance with the curve D of Fig. 2 and intended primarily for a heater voltage of 6 volts, the frequency change with a heater voltage of 5 volts was +30 cycles, the frequency change at $6\frac{1}{2}$ volts was +40 cycles, and the frequency change at 7 volts was +80 cycles.

With the heater 16 disconnected from the conductor 15, the same oscillator had a total drift of 1900 cycles when the heater supply was varied between 5 and 7 volts.

Consequently, my improved compensated tuned circuit enables me not only to provide for instant communication without appreciable drift immediately after the tube cathode heats up, but also enables me to use as the heater supply the battery charging system of an automotive vehicle in which the voltage varies considerably, without creating appreciable drift due to variation of the charging or battery voltage.

Although the invention has been described in connection with the details of a specific embodiment thereof, it must be understood that such details are not intended to be limitative of the invention, except in so far as set forth in the accompanying claims.

Having thus described my invention, I declare that what I claim is:

1. A temperature compensated tuned circuit having capacity and inductance connected in an operating circuit of a thermionic tube, a member arranged to heat up simultaneously with the tube, a thermal conductor having one end connected to said member and the other exposed to ambient temperature, said capacity including a capacitor having a negative temperature coefficient, and a thermal conductor thermally connected to said capacitor and to an intermediate point on first said conductor.

2. A temperature compensated tuned circuit having capacity and inductance connected in an operating circuit of a thermionic tube, a heater, means for supplying energy simultaneously to said heater and to the heater of the tube, a thermal conductor connected to said heater and to the chassis, said capacity including a capacitor having a negative temperature coefficient, and a second thermal conductor connected between said capacitor and an intermediate point on first said thermal conductor.

3. A temperature compensated tuned circuit having capacity and inductance connected in an operating circuit of a thermionic tube, a member arranged to heat up simultaneously with the tube, a thermal conductor having one end connected to said member and the other exposed to ambient temperature, said capacity including a capacitor having a negative temperature coefficient, and a thermal conductor having a relatively high thermal resistance connected between said capacitor and a point along first said thermal conductor.

4. A temperature compensated tuned circuit having capacity and inductance connected in an operative circuit of a thermionic tube, a heater, means for supplying energy simultaneously to said heater and to the heater of the tube, a thermal conductor connected to first said heater and to the chassis, said capacity including a capacitor having a temperature coefficient adapted to correct frequency drift due to heating up of the tube, and a second thermal conductor connected to said capacitor and to an intermediate point on first said thermal conductor.

5. A temperature compensated tuned circuit connected to a thermionic tube, a heater resistor, a thermal conductor extending from said resistor, switch controlled means for supplying energy to the heater of the tube and to the said resistor, said tuned circuit including a capacitor having a temperature coefficient of magnitude and sign to compensate for drift of frequency resulting from change of ambient temperature, and a thermal conductor connected to said capacitor and to an intermediate point of first said thermal conductor, the point of connection being located to control the supply and rate of supply of heat from said heater resistor to said capacitor to compensate for frequency drift resulting from heating up of the tube.

6. In an oscillator comprising a thermionic tube and a tuned circuit including capacitor means and inductor means connected to the tube, in combination, a resistor heater connected to the heater supply of the tube so that said heaters warm up together, a thermal conductor extending from said resistor heater to be warmed up thereby, said conductor being arranged to establish a temperature gradient therealong, said capacitor means including a capacitor having a negative temperature coefficient, and a second thermal conductor connected to said capacitor and to an intermediate point on first said thermal conductor.

7. In an oscillator comprising a thermionic tube and a tuned circuit including capacitor means and inductor means connected to the tube, in combination, a resistor heater connected to the heater supply of the tube so that said heaters warm up together, a thermal conductor extending from said resistor heater to be warmed up thereby, said conductor being arranged to establish a temperature gradient therealong, said capacitor means including a capacitor having a negative temperature coefficient of sufficient magnitude to compensate for frequency drift of the circuit with change of ambient temperature, and a second thermal conductor connected to said capacitor and to an intermediate point on first said thermal conductor, the point of connection of said thermal conductors being located to effect heating up of the capacitor to a degree sufficient to compensate for frequency drift due to the heating up of the tube elements, and the effective length of the second thermal conductor being arranged to provide heat resistance sufficient to limit the rate of heating up of the capacitor

to align substantially the change of capacity of the capacitor with the change of the characteristics of the tube during the tube heating period.

8. A temperature compensated tuned circuit comprising a pair of capacitors and inductor means connected in an operating circuit of a thermionic tube, said capacitors having temperature coefficients of magnitude and sign to compensate for frequency drift due to change of ambient temperature, a heater, means for supplying energy simultaneously to said heater and to the heater of the tube, a thermal conductor connected to said heater and arranged to establish a temperature gradient therealong, and a second thermal conductor connected to one of said capacitors and to an intermediate point on first said thermal conductor, last said capacitor having a temperature coefficient of sign tending with increase of temperature of the capacitor to compensate for frequency drift due to heating up of the tube, the point of connection between said thermal conductors being arranged to supply heat to last said capacitor at a rate and to an extent to compensate for drift of frequency due to heating up of the tube.

9. A temperature compensated tuned circuit comprising a capacitor and inductor connected in an operating circuit of a thermionic tube, a heater, a source of variable voltage, switch means for simultaneously connecting said source to said heater and to the heater of the tube, a thermal conductor connected to first said heater and arranged to establish a temperature gradient therealong, said capacitor having a temperature coefficient adapted to correct frequency drift due to heating up of the tube, and a second thermal conductor connected to said capacitor and to an intermediate point on first said thermal conductor, the point of connection being arranged to supply heat to said capacitor at a rate and to a final capacitor temperature whereby the change of capacity of the capacitor compensates for the frequency drift due to heating up of the tube.

10. A temperature compensated tuned circuit comprising a capacitor and inductor connected in an operating circuit of a thermionic tube having an indirectly heated cathode, a heater resistor, means for supplying current simultaneously to the heater of the tube and to said heater resistor, a thermal conductor connected to first said heater and arranged to establish a temperature gradient therealong, said capacitor having a temperature coefficient adapted to correct frequency drift due to heating up of the tube, and a second thermal conductor connected to said capacitor and to an intermediate point on first said thermal conductor.

11. A temperature compensated tuned circuit comprising a capacitor and inductor connected in an operating circuit of a thermionic tube having a predetermined rate of temperature rise upon energization, said capacitor and inductor having a smaller predetermined rate of temperature rise than said tube upon energization of said tube, said capacitor having a temperature coefficient of capacity change such that its temperature variation tends to compensate for frequency change due to a temperature variation in the same direction of said tube and inductance, means for generating heat, upon energization of said tube, a heat conducting path for the continuous flow of heat from said heat generating means, means for transferring heat from a point intermediate the ends of said heat con-

ducting path to said capacitor, said point being so chosen that said capacitor attains a final equilibrium temperature of such magnitude as to correlate the operating condition of said tube, capacitor, and inductor after they reach a constant temperature, said heat transferring means having such a characteristic that the rate of heat flow to said capacitor is at a rate such that the correlated operating condition of said tube, capacitor, and inductor is constant during their heating as well as after reaching equilibrium temperature.

12. A temperature compensated tuned circuit having capacity and inductance and including a reactive element having a negative temperature coefficient, connected in an operating circuit of a thermionic tube, a member arranged to heat up simultaneously with the tube, a thermal conductor having one end connected to said member and the other exposed to ambient temperature, and a thermal conductor thermally connected to said reactive element and to an intermediate point on first said conductor.

13. A temperature compensated tuned circuit connected to a thermionic tube, a heater resistor, a thermal conductor extending from said resistor, switch control means for supplying energy to the heater of the tube and to said resistor, said tuned circuit including a reactive element having a temperature coefficient of magnitude and sign to compensate for drift of frequency resulting from change of ambient temperature, and a thermal conductor connected to said reactive element and to an intermediate point of first said thermal conductor, the point of connection being located to control the supply and rate of supply of heat from said heater resistor to said reactive element to compensate for frequency drift resulting from heating up of the tube.

14. A temperature compensating arrangement for an electron discharge device having a heated electron emitting electrode and a cold electrode, comprising a reactance connected between said electrodes, the capacity between said electrodes being subject to change upon change in ambient temperature and change in temperature of said heated electrode, a source of heat arranged to heat up simultaneously with said heated electrode, a heat conducting path for the continuous flow of heat from said heat source, means for transferring heat from a point intermediate the ends of said heat conducting path to said reactance, said point being so chosen that said reactance attains a final equilibrium temperature of such magnitude that the change in capacity between said electrodes with temperature is substantially compensated, said heat transferring means having such a characteristic that heat flows to said reactance from said heat source at a rate such that heating of said reactance causes it substantially to compensate for capacity change between said electrodes during initial heating of said heated electrode.

15. A temperature compensating arrangement for an electron discharge device having a heated electron emitting electrode and a cold electrode, comprising a reactance connected between said electrodes, the capacity between said electrodes being subject to change upon change in ambient temperature and change in temperature of said heated electrode, a resistor arranged to heat up simultaneously with said heated electrode, a heat conducting path for the continuous flow of heat from said resistor, means for transferring heat from a point intermediate the ends of said heat

conducting path to said reactance, said point being so chosen that said reactance attains a final equilibrium temperature of such magnitude that the change in capacity between said electrodes with temperature is substantially compensated, said heat transferring means having such a characteristic that heat flows to said reactance from said resistor at a rate such that heating of said reactance causes it substantially to compensate for capacity change between said electrodes during initial heating of said heated electrode.

16. A temperature compensating arrangement for an electron discharge device comprising a reactance connected in an operating circuit of the device, a heater arranged to heat up upon energization of the device, a first thermal conductor having one end connected to said heater and the other exposed to ambient temperature, and a second thermal conductor thermally connected between said reactance and an intermediate point on said first thermal conductor, said reactance having a temperature coefficient of reactance change adapted to compensate for the long term reactance change of said electron discharge device due to the change of ambient temperature and also for the initial reactance change due to the heating up of the device.

17. A temperature compensating arrangement for an electron discharge device comprising a reactance connected in an operating circuit of the device, a heater arranged to heat up upon energization of the device, a first thermal conductor having one end connected to said heater and the other exposed to ambient temperature, and a second thermal conductor connected between said reactance and an intermediate point on said first thermal conductor, said reactance having a temperature coefficient of reactance change adapted to compensate for the long term reactance change of said electron discharge device due to change of ambient temperature and the point of connection of said second thermal conductor to said first thermal conductor being located to control the degree of temperature change of said reactance resulting from the heating up of said electron discharge device to compensate for initial reactance change resulting from said heating.

18. A temperature compensating arrangement for an electron discharge device comprising a reactance connected in the operating circuit of the device, a heater arranged to heat up upon energization of the device, a first thermal conductor having one end connected to said heater and the other exposed to ambient temperature, and a second thermal conductor thermally connected between said reactance and an intermediate point on said first thermal conductor, said reactance having a temperature coefficient of reactance change adapted to compensate for the long term reactance change of said electron discharge device due to the change of ambient temperature, the effective length of said second thermal conductor being arranged to provide heat resistance sufficient to limit the rate of heating up of said reactance to align substantially the reactance change of the reactance with the reactance change of the electron discharge device due to change of the parameters and characteristics of said device during its heating period.

19. A temperature compensating arrangement for an electron discharge device comprising a reactance connected in an operating circuit of the device, a heater arranged to heat up upon energization of said device, a chassis upon which

said discharge device is mounted; a first thermal conductor having one end connected to said heater and the other end connected to said chassis, whereby said other end is exposed to ambient temperature, and a second thermal conductor thermally connected between said reactance and an intermediate point on said first thermal conductor, said reactance having a temperature coefficient of reactance change adapted to compensate for the long term reactance change of said electron discharge device due to the change of ambient temperature and also for the initial reactance change due to the heating up of the device.

20. In a radio system arranged to maintain a characteristic of such system responsive to temperature changes in a predetermined manner, the combination of a source of heat produced in response to operation of the system, a temperature divider having one end in thermal contact with said heat source for the flow of heat therefrom, an impedance element connected electrically in said system and having impedance changeable with temperature in such a manner as to affect a characteristic of said system in a predetermined manner, and a heat conductor of predetermined characteristics disposed between a point intermediate the ends of said divider and said impedance, and arranged to transfer heat at such a rate from said point to said impedance element that the element is maintained at a substantially constant operating temperature in steady operation of the system at a constant ambient temperature and at such varying temperatures in transient operation of the system as to maintain a substantially constant operating condition of said system at a constant ambient temperature.

21. A temperature compensated tuned circuit having capacity and inductance connected in an operating circuit of a thermionic tube having a heater, a chassis, a heat source, means for supplying energy simultaneously to said heat source and to the heater of the tube, a thermal conductor connected to said heat source and to the chassis, said capacity including a capacitor having a negative temperature coefficient, and a second thermal conductor connected between said capacitor and an intermediate point on said first thermal conductor, said thermal conductors hav-

ing low electrical resistance whereby said capacitor is electrically connected to the chassis therethrough.

22. A temperature compensated tuned circuit having capacity and inductance connected in an operating circuit of a thermionic tube, a member arranged to heat up simultaneously with the tube, a second member subject to temperature change in response to change in ambient temperature, a thermal conductor connected between said members for the flow of heat therebetween, said capacity including a capacitor having a negative temperature coefficient, and a thermal conductor thermally connected to said capacitor and to an intermediate point on said first conductor.

23. A temperature compensated tuned circuit having capacity and inductance connected in an operating circuit of a thermionic tube, a member arranged to heat up simultaneously with the tube, a second member subject to temperature change in response to change in ambient temperature, a thermal conductor connected between said members for the flow of heat therebetween, said capacity including a capacitor having a negative temperature coefficient, and a thermal conductor thermally connected to said capacitor and to an intermediate point on said first conductor, said thermal conductors having low electrical resistance whereby said capacitor is electrically connected to the second member therethrough.

24. In apparatus for controlling electrical operation of a radio system subject to varying operating conditions in response to varying temperatures, said system including a compensating temperature responsive impedance element, the combination comprising means for producing heat simultaneously with operation of the system, a metallic connection having resistance to the flow of heat, means for transferring heat from said heat producing means through said metallic connection whereby a temperature gradient is produced therealong, and means including a second metallic connection for transferring heat from a point intermediate the end of said first metallic connection to said compensating element at a predetermined rate such that a compensating effect is produced on said system to reduce the effect of temperature change.

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