March 28, 1939. S. G. ELLIS 2,151,752

COMPENSATOR

Filed Jan. 9, 1937

Fig. 1.

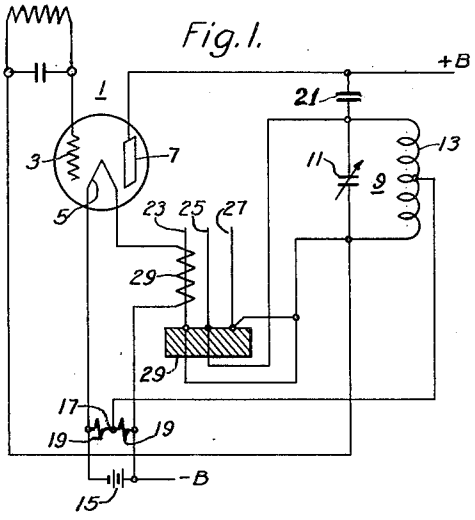



Fig. 2.

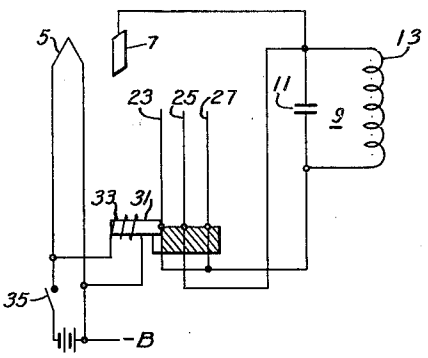



Fig. 3.

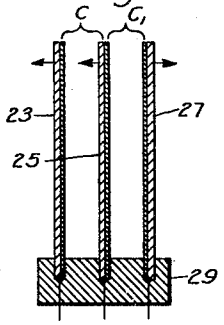



Fig. 4.

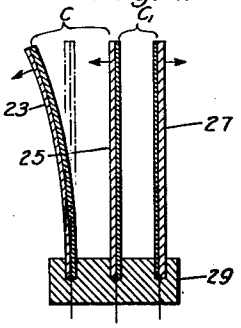



Fig. 5.

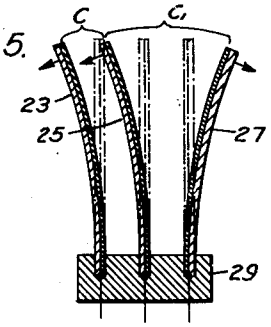
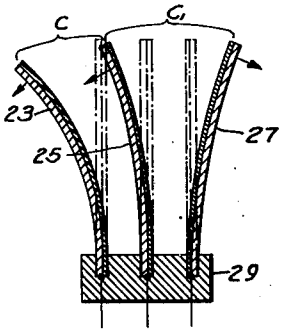



Fig. 6.




WITNESSES:

Fred C. Wilkins

C. Brosler

INVENTOR

Stuart G. Ellis, Deceased
by G. Arvilla Ellis, Administratrix

BY F. W. Lyle.

ATTORNEY

Patented Mar. 28, 1939

2,151,752

# UNITED STATES PATENT OFFICE

2,151,752

## COMPENSATOR

Stuart G. Ellis, deceased, late of Springfield, Mass., by G. Arvilla Ellis, administratrix, Springfield, Mass., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application January 9, 1937, Serial No. 119,816

11 Claims. (Cl. 250—27)

This invention relates to circuits of the radio type, and more particularly to such circuits requiring a high degree of frequency stability.

In the field of radio operation and analogous fields, wherein one deals with circuits in which currents at exceedingly high frequencies flow, the requirements concerning the frequency stability of the circuits becomes exceedingly rigid, particularly in such applications as in radio broadcasting, frequency measuring, etc. Such circuits, unless precautions are taken are prone to suffer changes in the constants of the elements entering into the make-up of the circuits, resulting in a shift in frequency from that for which the circuits were originally designed. The changes in the physical characteristics or constants of the circuit elements are attributed to expansion or contraction of frequency determining elements in the circuits, brought about primarily by changes in the ambient temperature and heating conditions in the apparatus.

With reference to electron discharge devices employed in circuits of this character, the heat developed in the cathode tends to cause expansion and flexure of the tube electrodes, thus altering the inter-electrode capacity existing between them. Since at least two of the electrodes in the discharge device are usually connected across a tuned circuit, it naturally follows that the capacity between these electrodes enters into the determination of the frequency to which the circuit will respond. Therefore any change in the inter-electrode capacity, brought about by the cathode heating current will cause a shift in the frequency adjustment of the circuit. When a circuit of this character is set into operation, an appreciable time will elapse before the inter-electrode capacity of the tube will reach a stable condition, and for this reason it is often necessary to delay operation until this condition has been reached.

The elements entering into the design of the tuned circuit may also cause frequency shifts, particularly when subjected to temperature variations, these temperature changes being of a rather unstable character in that they are usually due to changes in the ambient temperature surrounding the tuned circuit. Unless the tuned circuit is maintained in a thermostatically controlled heat chamber, it will be subject to the various changes mentioned.

It is an object of this invention to provide means which shall compensate for such changes occurring in the inter-electrode capacity of the electron discharge device to enable immediate use of the circuit after setting the circuit into operation.

Another object of this invention is to provide means for simultaneously correcting frequency shifts attributed to both the change in inter-electrode capacity of the electron discharge device and to changes in the elements of the tuned circuit.

Another object of this invention is to provide an exceedingly simple construction which will compensate for the shift in frequency resulting from a change of inter-electrode capacity as well as changes in the physical constants of the elements of the tuned circuit.

Another object of this invention is to provide a means for compensating for changes in inter-electrode capacity, which means shall be substantially unaffected by changes in ambient temperature.

Additional objects of this invention will be pointed out in the following description of the same, taken in conjunction with the accompanying drawing wherein:

Figure 1 is a circuit including a vacuum tube oscillator, in which has been embodied the invention as an example of its application to circuits of the radio type.

Fig. 2 is an illustration of a modification of this invention showing another manner in which the invention may be applied to radio circuits or the like, only a portion of the circuit of Fig. 1 being disclosed.

Fig. 3 is a structural illustration of the compensating device which has been disclosed schematically in the circuit of Fig. 1.

Fig. 4 is an illustration of this device depicting its operation and the manner of compensating for changes in inter-electrode capacity.

Fig. 5 is another illustration of this device showing its manner of operation to compensate for the effects of changes in ambient temperature upon the tuned circuit.

Fig. 6 is another view of the compensating device illustrating its manner of operation to compensate simultaneously for changes in inter-electrode capacity due to cathode heating, and changes in the tuned circuit constants due to variations in ambient temperature.

The embodiment of the invention as disclosed in Fig. 1 comprises a circuit of an oscillation generator of the Hartley type. This includes an electron discharge device 1 having grid 3, cathode 5 and plate electrodes 7, the grid and plate electrodes being effectively connected across the terminals of a tuned circuit 9, comprising a tuning

condenser 11 shunted by an inductance 13. The heating current for the cathode electrode is derived from a source of potential which may constitute a battery 15 or a suitable alternating current source. The mid-point 17 of the cathode circuit is obtained by bridging a pair of resistors 19 across the source of energy supply, the junction point of the two resistors being connected to a tap on the inductance 13 of the tuned circuit. The plate potential may be obtained from any suitable source, and will be applied across the terminals marked "—B" and "+B", there being a condenser 21 inserted in the circuit to isolate the plate potential from the grid circuit.

The device for compensating for changes in interelectrode capacity and in the constants of the tuned circuit comprises a plurality of heat responsive elements 23, 25 and 27, preferably of the bimetallic type, these being arranged in capacitive relationship to each other, which may be obtained by supporting them at one end to a common support 29. Two of the heat responsive elements 23 and 25 are so oriented with respect to each other and with respect to the third element 27 that for an increase in temperature, these two elements will distort in the same direction, which direction will be opposite to that in which the third element will distort. This is easily accomplished when using bimetallic elements by merely placing or mounting the elements, so that two elements which are intended to flex in the same direction have their surfaces of similar metal facing in the same direction. The first of these two elements 23 may be connected directly in the cathode circuit through a flexible connection at its upper end (not illustrated in the drawing) which will permit substantially free movement of the unsupported end of the element 23 in response to temperature changes. Or the heating current to the filament may be caused to affect the temperature responsive element by flowing through a resistor 29 surrounding the element 23. The temperature changes which will result in a flexing of the element 23 are those caused either directly as in the first case or indirectly as in the second case, by the current flowing in the cathode circuit. The remaining two elements are connected across the tuned circuit referred to. Where the resistor element 29 is employed for heating the temperature responsive element 23, the temperature responsive element is connected in parallel with the last element 27.

The physical dimensions of the bimetallic elements, the spacing between them and the sensitivity thereof are factors to be considered in designing the compensating device for satisfactory use in any particular apparatus. After the compensating device has been properly designed to match the apparatus with which it is to be used, and is connected in circuit therewith in a manner illustrated in Fig. 1, it will automatically compensate for changes occurring in the interelectrode capacity of the electron discharge device, and for changes in the constants of the tuned circuits, and this compensating action for both the tube and the tuned circuit will be taken care of simultaneously.

In Fig. 2 the construction of the compensating device departs from that of Fig. 1 in the manner of heating the tube capacity compensating element 23. In accordance with the disclosure of Fig. 2, this element has integrally united to it at its base, a block of metal 31 preferably one having good heat conducting properties such as copper, and the heating resistor 33 is wrapped around this block of metal, the resistor being connected directly across the filament circuit. A switch 35 common to both the resistor heating circuit and the filament circuit, assures simultaneous operation of both.

Referring to Figs. 3, 4, 5 and 6, the manner in which the action of the compensating device takes place will become apparent. In Figs. 1 and 2 the compensating device occupies a position in which none of the elements is flexed, and this can be assumed to be the situation at the instant of starting the radio circuit into operation. The arrows indicate the direction of flexure upon a rise in temperature, which can be obtained by proper orientation of the elements as pointed out above. The first of these elements is made responsive in accordance with the current in the cathode circuit in the various ways described above. This first element in combination with the second element is utilized to compensate for changes in the inter-electrode capacity of the tube, this being accomplished by causing the capacity between these two elements, indicated by "C" in the figure, to vary in accordance with the heat produced in the first element, which heat is derived from or in accordance with, the cathode circuit energy.

The second and third elements function to compensate for changes in the tuned circuit elements brought about by variations in the ambient temperature factor. The capacity between these two elements has been indicated as $C_1$ in the figure and this may be made to vary in response to ambient temperature.

The illustration in Fig. 4 pictures the condition of the device when ambient temperature remains unchanged, but the inter-electrode capacity of the tube has been altered. Under these conditions the first element which has been exposed to the current in the cathode circuit has flexed away from the second element to reduce or decrease the capacity between these two elements. This decrease is made to occur when the effect of the heating of the cathode results in an increase in the inter-electrode capacity of the tube.

In Fig. 5, the effects of a change in ambient temperature upon the compensating device is illustrated, it being assumed that no change in the inter-electrode capacity of the tube has occurred. It will be noted that, due to the particular orientation of the elements, the first two elements will flex in one direction, resulting in practically no change in the capacity C between these two elements. Since no change is desired under the conditions specified, a change in ambient temperature therefore will have no resulting effect upon the inter-electrode capacity compensating portion of the device. On the other hand, however, due to the fact that the third element is supported in a position which is reversed to that of the other two, it will flex in an opposite direction to decrease the capacity $C_1$ existing between the second and the last of the elements.

Since the effect of an increase in ambient temperature on the tuned circuit is to decrease its frequency, the decrease in the capacity $C_1$ of the compensating device will tend to increase the frequency, and thus may be made to compensate for the effects of the ambient temperature upon the tuned circuit.

Where both changes in the inter-electrode capacity and in the constants of the tuned circuits occur simultaneously, as may happen during the starting up or warming up period, the elements of the compensating device will flex

in a manner substantially as illustrated in Fig. 6. Both the first element and the second element will flex in the same direction due to the change in ambient temperature, but due to the added effect of the current in the cathode circuit, the first element will flex to a greater degree than the second and produce the proper decrease in capacity between the two, to compensate for such changes in inter-electrode capacity as occur during the warming up period. The effects of changes in ambient upon the tuned circuit will be compensated for by the decrease in capacity $C_1$ between the second and the last of the heat responsive elements.

The dotted lines in Figs. 4, 5 and 6 indicate the normal position of the elements such as is indicated in the device of Fig. 3.

It will be apparent from the above description that the invention provides a very simple means for maintaining frequency stability in a radio circuit. Not only does it accomplish this, but it has another important advantage in that it eliminates the necessity of delaying transmission or other operation of the circuit until the termination of the warming up period. Since the warming up time, particularly of transmitters or the like, is apt to extend over a period of from five to fifteen minutes, the importance of being able to utilize the circuit for transmission at the same time the circuit is set into operation should be quite apparent.

While this invention has been described in great detail, it is apparent that various changes may be made therein without departing from the scope of the invention.

The last bimetallic element 27 for example, may constitute just a plain strip of metal which is more or less insensitive to temperature effects. It need not be bimetallic in character, as a variable compensating capacity $C_1$ will still exist due to the temperature effects on bimetallic element 25. It will be apparent however, that to obtain similar capacity changes a variation in dimensions or spacing of the elements will be in order.

It is therefore desired that protection be not limited to these details except as may be required by the prior art and the appended claims.

It is claimed:

1. A device comprising a pair of temperature responsive elements supported in capacitive relationship to each other and adapted to flexurally respond in like manner to changes in ambient temperature, the value of said relationship thereby remaining substantially constant with variations in ambient temperature, and means for altering the temperature of one of said elements to a degree different from that of the other of said elements.

2. A device comprising a plurality of temperature responsive elements mounted on a common support in capacitive relationship one to another, said elements being oriented with respect to each other so that the capacity between the members of one combination of said elements is altered with a change in ambient temperature whereas the capacity between the members of another combination of said elements remains substantially unaltered for the same change in ambient temperature.

3. A circuit of the radio type including an electron discharge device having grid, cathode and plate electrodes, means for supplying heating energy to said cathode electrode, a tuned circuit connected between said anode and cathode electrodes, and means operated by said supply means for compensating capacitive changes in said discharge device which normally cause frequency shift and means physically coordinated with said compensating means, and simultaneously operable therewith for correcting changes in the constants of said tuned circuit.

4. A device comprising a pair of bimetallic temperature responsive elements supported in capacitive relationship to each other and oriented to respond in like manner to changes in ambient temperature whereby substantially no change of capacity occurs between said elements in response to changes in ambient temperature, and means for altering the temperature of one of said elements to a different degree than the other.

5. A device comprising a plurality of temperature responsive elements mounted on a common support in capacitive relationship one to another, said elements being oriented with respect to each other that the capacity between the members of one combination of said elements varies with a change in ambient temperature and the capacity between the members of another combination of said elements remains substantially unaltered for the same change in surrounding temperature.

6. A circuit of the radio type including an electron discharge having grid, cathode and plate electrodes, means for exciting said cathode electrode to a condition of electron emission, a tuned circuit connected between two of said electrodes, and means comprising a plurality of capacitively arranged temperature responsive elements for simultaneously compensating for changes in said discharge device tending to cause frequency shift and changes in the constants of said tuned circuit.

7. A device comprising a pair of bimetallic temperature responsive elements supported in capacitive relationship to each other and so coordinated as to have identical direction of flexure, whereby said elements will respond similarly to changes in ambient temperature maintaining said capacitive relationship substantially constant, and means for altering the temperature of one of said elements to a different degree than the other, effecting thereby a change in the capacity between said elements.

8. A device comprising a plurality of temperature responsive elements mounted in capacitive relationship one to another, said elements being oriented with respect to each other so that the capacity between the members of one combination of said elements varies with a change in ambient temperature and the capacity between the members of another combination of said elements remains substantially unaltered for the same change in surrounding temperature.

9. A circuit of the radio type including an electron discharge device having grid, cathode and plate electrodes, means for exciting said cathode electrode to a condition of electron emission, a tuned circuit connected between two of said electrodes, and means for simultaneously compensating for changes in capacity between electrodes of said discharge device and changes in the constants of said tuned circuit, said means comprising a plurality of temperature responsive elements mounted in capacitive relationship one to another, certain of said elements reacting on the effective capacity of said tuned circuit being oriented with respect to each other so that the capacity between their members varies with a change in ambient temperature and one of said elements influenced by said exciting means coacting with other of said elements.

10. A device comprising a pair of temperature

responsive elements supported in capacitive relationship to each other and adapted to respond in like manner to changes in ambient temperature whereby said capacitive relationship remains substantially constant despite changes in ambient temperature, means for altering the temperature of one of said elements to a different degree than the other, and an additional element located in capacitive relationship to one of said pair of elements, said additional element having temperature responsive characteristics differing from those of said element with which it is in capacitive relationship, effecting a change in degree of said relationship upon a change in ambient temperature.

11. A circuit of the radio type including an electron discharge device having a cathode and additional electrodes capacitively related to each other, a circuit for said cathode including means for feeding current thereto to heat the same, a device comprising a pair of elements, at least one of said elements being heat responsive, means for supporting said elements in capacitive relationship to each other, and means for increasing the temperature of said heat responsive element by the thermal effect of the currents flowing in said cathode circuit.

G. ARVILLA ELLIS.
*Administratrix of the Estate of Stuart G. Ellis, Deceased.*