

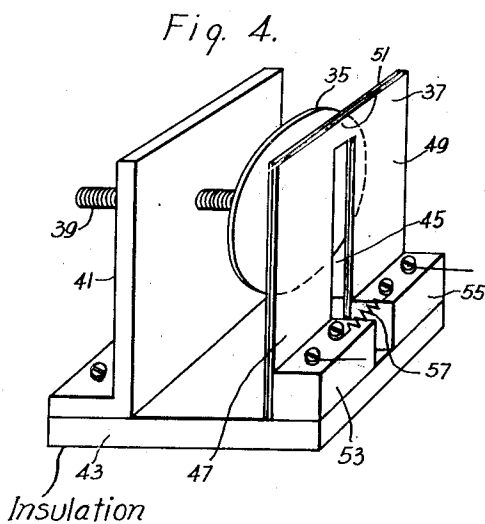
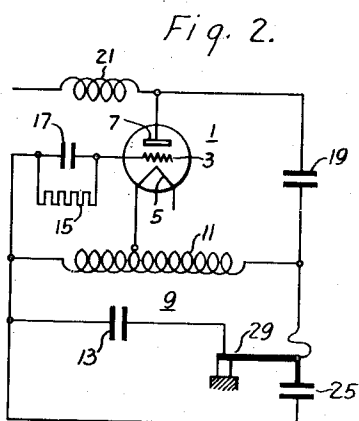
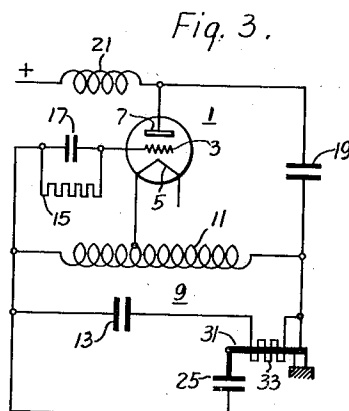
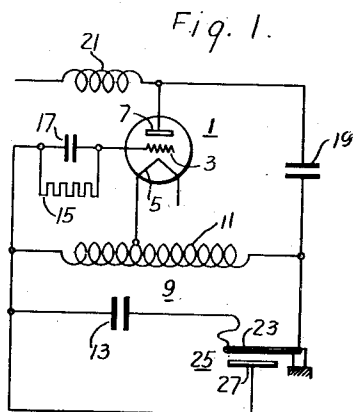
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2,114,846

FREQUENCY STABILIZING DEVICE

Filed Nov. 29, 1935



WITNESSES:

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FREQUENCY STABILIZING DEVICE

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Pennsylvania

Application November 29, 1935, Serial No. 52,113

15 Claims. (Cl. 250—36)

My invention relates to an oscillation genera-
tor, more particularly to means for stabilizing the
frequency thereof.

It is an object of my invention to provide an
oscillation generator in which frequency varia-
tion due to temperature changes shall be mate-
rially reduced.

Another object of my invention is to improve
the frequency stability of oscillation generators
by the addition of a compensating element which
shall respond immediately to any tendency to-
ward a frequency change of the oscillator.

A further object of my invention is to provide
a frequency stabilizing device for oscillators which
may be operated in any oscillator embodying
electron discharge devices.

An additional object of my invention resides in
the method for compensating for undesired fre-
quency changes occurring in oscillation genera-
tors.

Further objects of my invention will be dis-
closed in the following description of the same,
taken in connection with the accompanying draw-
ing, wherein

Figs. 1, 2 and 3 represent an oscillation genera-
tor circuit of the well known Hartley type, in each
of which circuits a different species of my inven-
tion is embodied; and,

Fig. 4 is a view in perspective of one form which
my compensating device may take.

In general, my invention comprises the idea
of utilizing an element having high temperature
coefficient response to vary a compensating ca-
pacitor in an oscillation generator, and exposing
said element to that portion of the oscillator
wherein the high frequency currents flow, in such
a manner that the heat produced in the tempera-
ture responsive element shall, for all practical
purposes, be strictly in accordance with the cur-
rent flowing in these circuits.

My invention further embodies the design of
the high temperature coefficient element so that
it will respond in a manner proportional to the
changes taking place in the frequency determin-
ing elements of the oscillators or more practically
speaking, in accordance with changes occurring
in the tank coil, since the coil is mainly responsi-
ble for the frequency shift of an oscillator due to
temperature variations.

It has been known in the prior art to broadly
utilize temperature responsive elements to com-
pensate for frequency changes in an oscillation
generator due to change of temperatures in and
around the frequency determining elements. In

the known circuits, however, the frequency re-
sponsive element was disposed in such a position
that it received its heat by radiation, or convec-
tion of the heat generated in the elements of the
circuit as well as from the heat conducted into
the vicinity from the outside.

The frequency of a resonant circuit is affected
by changes in physical dimensions brought about
by changes in temperature of the frequency de-
termining elements of the circuit. Such changes
in temperature are practically due entirely to
(first) power losses in the coil, which losses are
a function of the current, and (secondly) varia-
tions in ambient temperature.

Bimetallic compensating devices utilized in the
manner stated cannot operate efficiently nor pro-
vide sensitive control of the frequency of an oscil-
lator, and an analysis of its operation discloses
as the reason thereof, that the compensating de-
vices do not respond equally well for temperature
changes of the circuit elements caused by power
losses in the circuit as for temperature changes
caused by variations in ambient temperature. A
fifty degree rise in the temperature of the fre-
quency determining elements might for instance
produce a temperature effect on the compensator
equivalent, say, to only a five or ten degree rise
in ambient temperature, and obviously under such
conditions, the compensator cannot exert a com-
pensating effect which will be an accurate meas-
ure of the temperature of such elements.

It is further apparent that where the heat,
originating by power losses in the circuit, must
arrive at the compensating element by way of
convection or radiation, an appreciable time lag
must ensue between the time that the heat is
generated at its source, and the time at which it
produces a response in the temperature respon-
sive element. It will be further apparent that
should the heat thus developed, fluctuate, as
might happen when the operation of the oscil-
lator is a periodic one, the frequency of the oscil-
lator will never attain a condition of stability;
in that, due to the time lag referred to, the fre-
quency of the oscillator will fluctuate in accord-
ance with the operation fluctuations. The cause
and effect do not occur close enough in time to
approach the ideal conditions for compensation.

Since the power losses in the resonant circuit
are a function of the current flowing there-
through, changes in heat generated in any ele-
ment carrying this current will be a measure of
a change in temperature of the circuit caused by
a change in the current flowing therethrough. I

make use of this fact in obtaining compensation in an oscillator which will be efficient, sensitive and accurate.

In accordance with one embodiment of my invention, I provide a compensating condenser at least one element of which is of a temperature responsive material, preferably of the bimetallic type, this element being provided with terminals at distributed locations and connected in as a part of the oscillatory circuit which carries the high frequency current. The heat produced in the temperature compensating element will be the direct result of the oscillatory current flowing through this element, thus providing assurance that the heat produced in the compensating device will occur simultaneously with the heat developed in the oscillator circuit itself, by reason of the flow of the oscillatory current there-through. The question of a time lag therefore is practically eliminated and the compensating effect of the compensating condenser will occur practically instantaneously and, therefore, will compensate at the instant at which the compensation is necessary, to obtain a resulting stabilized frequency of oscillations in the oscillator, and not after an elapsed interval of time.

The bimetallic element must furthermore be so designed that for each degree change in the temperature of the frequency determining elements caused by power losses, its temperature must change an amount equal to that which would occur, had the degree change in temperature of the frequency determining elements been brought about by a variation in ambient temperature. The resistance of the bimetallic element will not appreciably govern its characteristics in response to ambient temperatures, but will materially alter its response characteristics when responding to heat developed from electric current flowing therethrough, and consequently its size and shape must be such as to offer the proper resistance to current flow, which is necessary to correlate its response to current changes with changes in ambient temperature. This condition will be satisfied to a high degree if the bimetallic element be so designed that the ratio of the I^2R losses developed therein to the mass of the element times its specific heat, is made equal to the ratio of the I^2R losses of the coil to the coil mass, times its specific heat. Expressed as a formula;

$$\frac{I^2R}{\text{Mass} \times \text{Specific heat}} \text{ of coil} = \frac{I^2R}{\text{Mass} \times \text{Specific heat}}$$

of bimetallic element. When so designed, the bimetallic element will respond in proportion to the changes simultaneously occurring in the coil, regardless of whether such changes in the coil are brought about by changes in the oscillating current or load, or changes in ambient temperature.

To maintain a compensated condition, it is essential that for the steady condition of operation of the oscillator, the design of the bimetallic element must also be such that the ratio of the I^2R losses developed therein to the heat lost by radiation and convection must equal the ratio of the heat developed in the coil during a steady condition, to the heat lost from the coil by radiation and convection.

With both of the above conditions satisfied, the compensating condenser, of which the bimetallic element comprises a controlling element in determining its instantaneous capacity, will vary in capacity in proportion to the changes

in inductance occurring in the coil, whatever the causes of such inductance changes may be.

In general the spacing of the compensating condenser should be large compared to its movement so that the capacity change per unit change of temperature will approximate a straight line. If then the change of coil inductance per unit change of temperature is a straight line these quantities may be made equal and opposite to effect exact compensation. Obviously, other than straight line relations may be utilized provided that the coil and compensator effects are equal and opposite at any temperature within the limits designed for.

The changes in the compensating condenser will then be proportional to the changes in the inductance of the coil, the constant of proportionality being equal to the ratio of the total original capacity of the tank circuit divided by the original inductance of the coil.

In Fig. 1, I have disclosed a conventional oscillation generator circuit of the Hartley type embodying an electron discharge device 1 having grid 3, cathode 5 and anode 7 electrodes, the grid and anode electrodes being connected to the extremities of a resonant circuit 9 comprising an inductor 11 shunted by a condenser 13. A grid leak 15 and condenser 17 are connected in the lead to the grid, and a blocking condenser 19 in the lead to the anode, anode potential being supplied to the plate electrode through a choke coil 21, the blocking condenser referred to, preventing direct-current potential from being applied through the tank coil to the grid.

In accordance with the embodiment of my invention as described above, the bimetallic plate 23 of a compensating condenser 25 is connected in the oscillatory circuit, in series with the tank condenser 13, for example. The oscillating current flowing in the tank circuit will, therefore, have to flow through the bimetallic plate. The other plate 27 of the compensating condenser may be connected to the other side of the tank condenser, thus placing the compensating condenser effectively in shunt to the main tank condenser. Thus, should the load on the oscillator change to such an extent as to increase or decrease the oscillatory current flowing in the tank circuit which in the normal course of events, would alter its frequency, the bimetallic condenser plate 23 will immediately respond one way or the other to the change in the current flowing therethrough, and immediately change the compensating capacity in shunt to the main condenser. The resonant frequency of the tank circuit will thereby be effectively maintained at its desired value and the frequency of the generator will remain practically constant.

In the circuit of Fig. 2, the compensating means also comprises a condenser 25 of the variable type, the adjustment of which is mechanically controlled by the movement of a bimetallic element 29. The bimetallic element is connected directly in the current path of the oscillator current in the tank circuit of the oscillation generator, and its movement in response to heat changes brought about by changes in the oscillatory current flowing in the tank circuit will control the value of the compensating capacitor, which may be connected in shunt to the main tank condenser in a manner somewhat similar to that of Fig. 1.

In the circuit of Fig. 3, we also have a compensating condenser 25 in which the adjustment is controlled mechanically by the movement of a bimetallic element 31. This modification, how-

ever, differs from that of Fig. 2 in that the bimetallic element is not connected directly in the main portion of the tank circuit, but practically the same effect is obtained by means of a resistor 33 connected in the circuit and adjacent to or wrapped around the bimetallic element 31. The resistor now constitutes a portion of the tank circuit where heat in concentrated form will be developed by the high frequency currents flowing therethrough. By placing the bimetallic element adjacent to the resistor where the heat is concentrated, it will become very sensitive to changes in high frequency current values and practically the same effect and speed of compensation can be obtained, as if the bimetallic element itself were connected in the main tank circuit and conducted the oscillatory current therethrough.

In designing the bimetallic or heat responsive element of the compensating condenser, if we provide per unit length of both bimetallic material and tank circuit coil conductor, surfaces equal in area and of like radiation characteristics, make the mass times specific heat the same, and make the respective radio frequency resistance the same, conditions will be ideal for exact compensation for both transient and steady state conditions; that is if currents of similar value are made to flow through both coil and compensator. Where a different value of current or equivalent heat loss is developed in the compensator, the values of the physical and electrical characteristics of the bimetallic element may be changed. It is only necessary that the various ratios mentioned above be maintained in order to obtain idea compensating results.

An approach to the ideal condition may be realized by employing a bimetallic or heat responsive element of convenient dimensions and loading the same by adding thermal mass to the element. This may be done by soldering blocks of copper or other suitable metallic material to the bimetal element, the size and shape of the blocks being such as will approximate the ratio of I^2R losses in the element to its mass times specific heat, and that ratio of the I^2R losses in the element to its losses by radiation and convection, which are necessary for matching the operating characteristics with the changes occurring in the coil.

One practical form of a compensating condenser which my invention may assume, is illustrated in the device of Fig. 4 and it comprises two plates 35 and 37, one circular in shape and adjustably supported by means of a threaded bolt 39 through a supporting wall 41 of conductive material mounted on a base member 43 of insulating material. The other element or plate 37 of the condenser comprises the temperature responsive element which, for efficient operation, should consist of a bimetallic plate. In the form shown by me, it comprises a plate rectangular in shape and provided with a slot 45 through the central portion extending from one edge to a point near the opposite edge, leaving two large sections 47 and 49 joined by a strip 51 at the top. The plate can be mounted in upright position on the base 43 by attaching it to terminal lugs 53 and 55 of conductive material also mounted on the base. The capacity of the condenser may be adjusted manually by varying the spacing between the circular plate 35 and the bimetallic element 37, by reason of the threaded engagement of the circular plate in its supporting wall.

The sensitivity of the device, on the other hand, can be varied by changing the size of the slot

45 in the bimetallic element. While only one slot has been shown in the plate 37, the resistance of the plate may be increased by providing additional slots extending alternately from both the upper and lower edges thereof.

The direction of compensation can be controlled by mounting the bimetallic element with either one face of the other, facing the circular plate, whereupon the capacity of the compensating condenser may be made to increase or decrease upon heating of the bimetallic plate.

The size of the terminal blocks 53 and 55 will depend upon the amount of thermal mass and radiation surface found necessary to be added to the bimetallic element to match it with the coil 15 in the tank circuit.

The above described compensating condenser is applicable in the circuit arrangement of Fig. 1. Where, however, it is desired to utilize the embodiments of Figs. 2 and 3, an additional element will be added to the construction illustrated in Fig. 4. This additional element will comprise a plate in capacitive relationship to the circular plate shown and it will be mechanically coupled to the bimetallic element which will now control the movement of the added plate, and not constitute a portion of the compensating capacity.

Once the bimetallic element has been shaped and slotted, it will not be desirable to alter its size or shape to change its sensitivity. In fact, the sensitivity could be changed in one direction only and that would be by enlarging the slot or providing additional slots as pointed out above. Should the design of the circuit or other factors necessitate a decrease in the sensitivity of the compensating condenser, the result can very easily be accomplished by connecting a shunt 57 across the terminal blocks, whereby a portion of the oscillator current, which would normally go into heating up the bimetallic plate will be shunted around it and the effect on the bimetallic element will be reduced as desired.

The compensating means of my invention responds effectively to both changes in ambient temperature and changes in load, and when once adjusted to compensate for changes in circuit constants due to current, it will at the same time compensate for such changes when due to variations in ambient temperature, to maintain a stabilized frequency condition of the oscillator. Should either the load condition or the ambient temperature remain constant, it is apparent that compensation will still occur due to changes in the other, which might tend to disturb the frequency equilibrium of the circuit.

Should the frequency stability requirement for any particular circuit be so stringent as to require taking into consideration such comparatively minor effects on the frequency as might be attributed to temperature effects on the tank condenser and leads, etc., the compensating condenser may well be adjusted to take care of such changes, the manner of adjusting said condenser having been pointed out above in the description of the device of Fig. 4.

While I have disclosed my invention in detail, it is apparent that various modifications of the same would be apparent to one skilled in the art and I, therefore, do not desire to be limited in my protection to the details disclosed by me except as may be necessitated by the prior art and the appended claims.

I claim as my invention:

1. In combination, an oscillation generator comprising inductance and capacity for deter-

mining the frequency of oscillation thereof, said inductor being normally heated due to oscillatory current in said generator, means for compensating for frequency changes normally arising out of changes in said current, said means comprising a compensating condenser including a bimetallic element, said bimetallic element being coupled into said oscillation generator to pass current in proportion to the current flowing in said oscillation generator, and having a ratio of heat developed therein by said current to the product of its mass times its specific heat substantially equal to corresponding ratio with respect to said inductance.

2. For use in combination with an oscillation generator to compensate for frequency changes therein, a condenser having one plate of bimetallic material and terminal connections at two points on said plate whereby current may be conducted along this plate to the exclusion of the other plate.

3. For use in combination with an oscillation generator to compensate for frequency changes therein, a condenser comprising a bimetallic element and terminal connections at two points on said bimetallic element whereby current may be conducted therealong, said bimetallic element constituting a plate of said condenser.

4. In combination, an oscillation generator comprising inductance and capacity for determining the frequency of oscillation thereof, means for compensating for frequency changes normally arising out of changes in load current said means comprising a condenser including a bimetallic element, an impedance connected in circuit to carry current proportional to the oscillatory current in said generator, said bimetallic element being disposed adjacent to said impedance and adapted to be effectively heated thereby.

5. In combination, an oscillatory circuit comprising an inductor, said inductor having heat developed therein in accordance with current in said circuit, and a frequency stabilizing device connected in circuit therewith and having heat developed therein in accordance with current in said circuit, said frequency stabilizing device having a ratio of heat developed therein to the product of its mass times its specific heat substantially equal to the ratio of heat developed in said inductor to the product of the mass of said inductor times its specific heat.

6. In combination, an oscillatory circuit comprising an inductor and a compensating condenser, said inductor having heat developed therein in accordance with current in said circuit, said compensating condenser embodying a bimetallic control element in series with said inductor and adapted to carry the current flowing through said inductor to develop heat in said bimetallic element, said bimetallic element having a ratio of heat developed therein to the product of its mass times its specific heat substantially equal to the ratio of heat developed in said inductor to the product of the mass of said inductor times its specific heat.

7. In combination, an oscillatory circuit comprising an inductor and a frequency stabilizing device comprising a compensating condenser having a controlling element of bimetallic material, both said inductor and controlling element having heat developed therein due to oscillatory current in said circuit and thermal mass loading means embodied in said frequency stabilizing device to make a ratio of heat generated therein to the product of its mass times its specific heat

substantially equal to the ratio of heat developed in said inductor to the product of the mass of said inductor times its specific heat.

8. In combination, an inductive and capacitive reactance connected to constitute a tuned circuit, said reactances being adapted to have heat developed therein in accordance with oscillatory current in said tuned circuit whereby the frequency of said tuned circuit is prone to shift upon a change in said current, said reactances having a certain ratio of heat developed therein to their combined masses times their specific heats, a compensating reactance connected in circuit with said tuned circuit for compensating for such shifts in frequency, said compensating reactance also being adapted to have heat developed therein in accordance with oscillatory current in said tuned circuit, said compensating reactance having a ratio of heat developed therein to its mass times its specific heat which ratio is substantially equal to that of said reactances combined.

9. In combination in a tuned circuit, an inductor adapted to have heat developed therein due to oscillatory current in said tuned circuit, said inductor having a certain ratio of heat developed therein to its mass times specific heat, a condenser having a plate thereof temperature responsive and adapted to have heat developed therein in accordance with oscillatory current in said tuned circuit, said condenser having a ratio of heat developed therein to its mass times its specific heat which ratio is substantially equal to that of said inductor.

10. In combination with an impedance which changes in magnitude in response to temperature rise connected in an electric circuit, said impedance being adapted to have heat developed therein in accordance with current flowing in said circuit, said impedance having a certain ratio of heat developed therein to the product of its mass by its specific heat, a compensating means which responds to temperature rise connected in said circuit and adapted to have heat developed in it in accordance with current flow in said circuit and thereby to be altered to compensate the change in said impedance due to said heat developed therein, said compensating means having a ratio of heat developed therein to the product of its mass by its specific heat which is substantially equal to the ratio first mentioned.

11. In combination with an impedance which changes in magnitude in response to temperature rise connected in an electric circuit, said impedance being adapted to have heat developed therein in accordance with current flow in said circuit, said impedance having a certain ratio of heat developed therein to the product of its mass by its specific heat, a compensating means which responds to temperature rise to compensate the first-mentioned change connected in said circuit and adapted to have heat developed in it in accordance with current flow in said circuit, said compensating means having a ratio of heat developed therein to the product of its mass by its specific heat which is substantially equal to the ratio first mentioned, the temperature change produced in said compensating means and in said impedance by a given current flow in said circuit being substantially equal.

12. In combination with a first impedance and a second impedance of opposite sign connected to constitute an electric circuit at least said first impedance changing in magnitude in response to temperature rise, said impedances being adapted to have heat developed therein in accordance

with the current flowing in said circuit, said first impedance having a certain ratio of heat developed therein to the product of its mass by its specific heat, a temperature-responsive compensating means connected in said circuit and adapted to have heat developed therein in accordance with the current flow in said circuit, said compensating means being adapted to be so altered by a given ambient temperature rise as to change said second impedance in an equal percentage but in opposite sense to the first-mentioned change, said compensating means having a ratio of heat developed therein to the product of its mass by its specific heat which is substantially equal to the first-mentioned ratio, and the temperature rises produced respectively in said one impedance and in said compensating means by a given current flow in said circuit being substantially equal.

13. In combination with a first impedance and a second impedance of opposite sign connected to constitute an electric circuit at least said first impedance changing in magnitude in response to temperature rise, said impedances being adapted to have heat developed therein in accordance with the current flowing in said circuit, said first impedance having a certain ratio of heat developed therein to the product of its mass by its specific heat, a temperature-responsive compensating means connected in said circuit

and adapted to be heated by current flow therein, said compensating means being adapted to be so altered by temperature rise as to change said second impedance in opposite sense to the first-mentioned change, said compensating means having a ratio of heat developed therein to the product of its mass by its specific heat which is substantially equal to the first-mentioned ratio.

14. In combination in a tuned circuit, a variable condenser, a heat-responsive element and means for causing it to vary said condenser, an inductor comprising a conductor, each unit length of said element and said inductor having equal areas and being of like heat-dissipation characteristics, the product of the mass by the specific heat of the respective said unit lengths being equal, and the radio-frequency resistances of the respective said unit lengths also being equal.

15. In combination in a tuned circuit, a variable condenser, a heat-responsive element and means for causing it to vary said condenser, an inductor comprising a conductor, each unit length of said element and said inductor having equal areas and being of like heat-dissipation characteristics, and the radio-frequency resistances of the respective said unit lengths also being equal.

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