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TEMPERATURE COMPENSATION MEANS FOR FIXED REACTANCES IN A TUNABLE CIRCUIT

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2 Sheets-Sheet 2

POWDERED METAL CORE
OF ONE MATERIAL 52

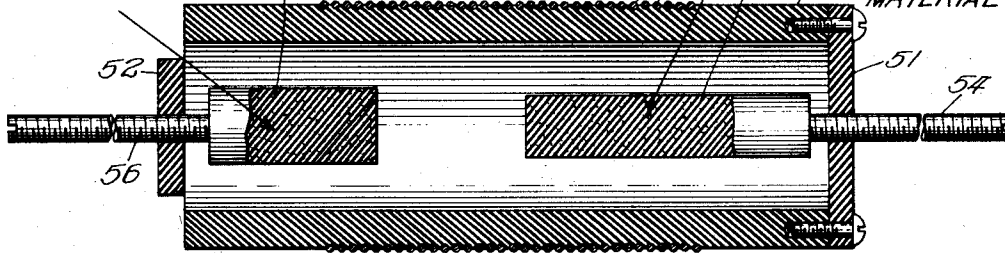


Fig. 6.

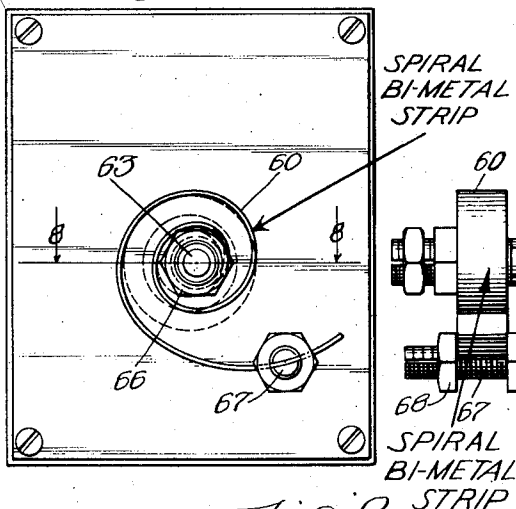


Fig. 7.

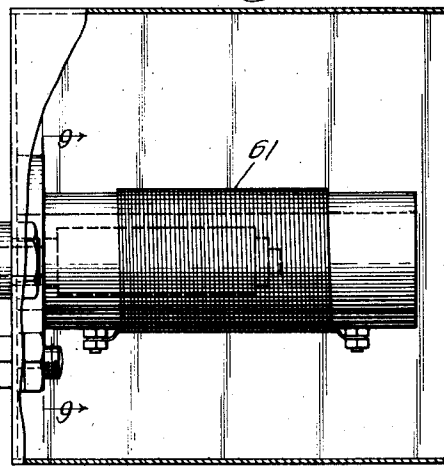


Fig. 8.

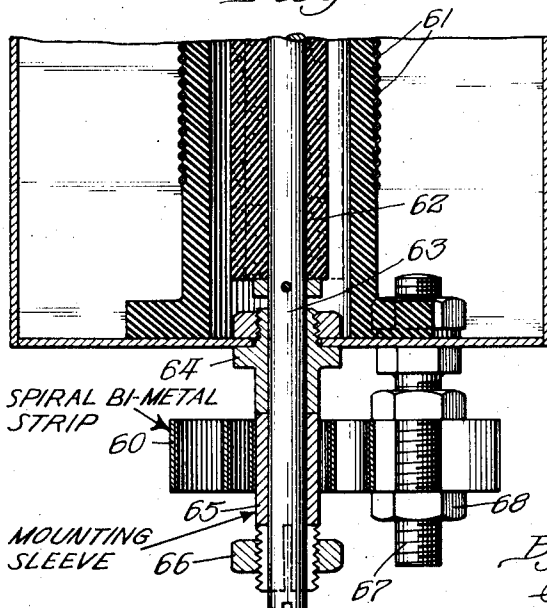
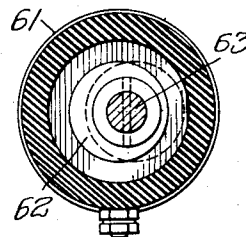


Fig. 9.



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UNITED STATES PATENT OFFICE

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TEMPERATURE COMPENSATION MEANS
FOR FIXED REACTANCES IN TUNABLE
CIRCUITSTheodore A. Hunter, Iowa City, Iowa, assignor to
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12 Claims. (Cl. 250—40)

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This invention relates to temperature compensation, and more particularly to adjustable means for compensating for variations in the impedance of the tuned circuit and elements thereof as a result of temperature variations.

One feature of this invention is that it provides means for accurately compensating for variations which would otherwise be occasioned by temperature variations; still another feature of this invention is that it provides means for readily adjusting the compensation factor or coefficient to meet manufacturing variations and to permit accurate compensation under production conditions; yet another feature is that such adjustment may be made without changing, at the temperature at which the adjustment is being made, the impedance of the circuit element with which the compensating means is associated; and a further feature is that the temperature compensating means is rugged and stable under adverse conditions, as heavy vibration. Other features and advantages of this invention will be apparent from the following specification and drawings, in which:

Figure 1 is a side elevation, partly broken away, of an oscillator tuning unit embodying a preferred form of my invention; Figure 2 is a front view of the unit shown in Figure 1; Figure 3 is a fragmentary transverse sectional view along the line 3—3 of Figure 1; Figure 4 is a schematic circuit representation of this tuning unit; Figure 5 is a view, principally in longitudinal section, of another embodiment of my invention; Figure 6 is a front view of a tuning unit embodying still another modification of my invention; Figure 7 is a side view, partly broken away, of this unit; Figure 8 is a sectional view, partly broken away, along the line 8—8 of Figure 6; and Figure 9 is a transverse detail view, principally in section, along the line 9—9 of Figure 7.

In so far as they are known to applicant, previous attempts to provide compensation for variations in impedance of a circuit element upon variations in temperature have been in connection with the condenser of a tuning circuit, generally by the provision of a separate small condenser whose sole function was temperature compensation. Such an arrangement, however, provides the same amount of capacity change per unit of temperature change regardless of the frequency to which the circuit may be tuned, rather than providing a compensation which was always a given percentage of the condenser reactance, as it should be; and adjustability of the compensation coefficient (the amount of

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change of reactance per unit of temperature change) was lacking. My invention obviates these disadvantages, provides a very stable and rugged compensating arrangement with a linear action and with means for readily adjusting the compensation coefficient, this latter being very important in that it enables manufacturing variations to be compensated for in production.

In the particular embodiment of my invention illustrated in Figures 1-4 a tuning unit, adapted to be associated with an oscillator, is indicated in general as 10. This unit comprises a coil 11 in parallel with a variable condenser 12 to provide the tank circuit of an oscillator when properly associated with a tube and other elements. Even though every effort is made to provide the minimum temperature coefficient of these circuit elements, the tank circuit will usually have a positive temperature coefficient of 10 or 15 parts per million; that is, its impedance increases to this extent per degree of temperature rise, the frequency to which it is resonant similarly decreasing. Where no special effort is made to eliminate the effect of temperature variations a tank circuit will commonly have a positive coefficient of from 30 to 100 parts per million per degree centigrade.

Where a tuning circuit must operate through wide ranges of temperature, as in an aircraft radio, this temperature change can cause a very appreciable frequency change. It is to prevent this change that I have introduced temperature compensation. Previous efforts in this regard have been unsatisfactory for a number of reasons, the principal one being that they lacked ready adjustability. In commercial production two similar tuned circuits may have widely different temperature coefficients, and accurate and satisfactory compensation cannot be obtained except by an arrangement which permits each tuning circuit compensating means to be adjusted to meet its particular conditions.

I have found that it is much more advantageous to provide temperature compensation in connection with the coil of a tuned circuit rather than in connection with the condenser. It is now becoming quite common to introduce a permeability core (comprising fine metallic particles in an appropriate binder or base material) into a coil to increase its inductance for a given size and number of turns and I take advantage of this by providing for movement between the core and coil to effect the desired temperature compensation, this movement being automatically effected by temperature responsive means.

Depending upon the direction and extent of movement provided in this way, any desired temperature coefficient, either positive or negative, may be provided for the compensating action.

In the embodiment now being discussed a permeability core 13 is mounted on a shaft 14 of insulating material, this shaft being threaded into a nut 15 carried by a bi-metal strip or plate 16. The bi-metal plate has its four corners rigidly connected, as by bolts 17 and spacers 18 to the front plate 19 of the tank circuit housing. This plate is provided with slots 20 and 21, and the bi-metal plate 16 is provided with registering slots 22 and 23, these slots being symmetrically arranged on each side of the shaft 14 with their axes lying along a line through the center of such shaft. An adjustment bolt 24 is adapted to pass through and be movable in the slots 20 and 22, this bolt being provided with a cooperating spacer 25; and a similar adjustment bolt 26 is movable in the slots 21 and 23 and is provided with a spacer 27.

As may be best seen in Figure 3, the bi-metal plate 16 is here arranged to bulge outwardly upon increase in temperature, the core being moved out of the coil by this movement of the center of the plate to reduce its effect upon the coil (and thus the inductance of the coil) as the temperature rises. At low temperatures the strip would straighten out more, as shown in dotted lines, resulting in an increased effect of the core upon the coil inductance.

As long as the movement of the core is such that the inductance of the coil does not too closely approach that at the ends of the permeability tuning curve the change of inductance per unit of movement will be linear for all practical purposes; and a bi-metal strip or plate of the character shown has a lineal movement, in response to temperature changes, within three or four per cent, throughout ranges from 100° above zero to 50° (centigrade) below, the action still remaining reasonably linear even beyond such temperatures. It will thus be apparent that a very accurate and linear temperature compensation action is accomplished throughout wide temperature ranges.

The amount of inductance change per unit of shaft movement may be initially determined by the size of the core used in relation to a given coil, and by the spacing between the turns of the coil, so that such a unit can be designed to provide a positive coefficient in the neighborhood of 10 parts per million or in the neighborhood of 100 parts per million, or practically any compensation that may be desired, either positive or negative. Accurate adjustment of the compensation coefficient to the conditions of the particular element or circuit may thereafter be made by movement of the adjusting bolts 24 and 26. In whatever position these bolts are placed they immobilize the ends or portions of the bi-metal strip lying beyond them, and the positioning of these bolts therefore determines the effective length of the active center portion of the strip, and thus the movement of the shaft per degree change of temperature. In the particular embodiment of my invention illustrated herein, with elements designed to have low temperature coefficients, movement of the adjusting bolts from their position closest to the shaft to their position farthest removed therefrom resulted in a variation of the compensation action between 6 and 18 parts per million per degree centigrade,

a sufficient range to enable accurate compensation for manufacturing variations and very precise maintenance of the desired frequency of the tuned circuit during wide ranges in the temperatures at which it operated.

In making the final adjustments on the oscillator the workman first effects the desired factory adjustment to a desired operating frequency, this adjustment sometimes being termed "trimming" by rotating the shaft 14 in its threaded mounting in the nut 15 until the oscillator frequency at a predetermined point in its tuning range, as for example minimum frequency position of the tuning knob, corresponds with a predetermined calibrating frequency, thereafter locking the shaft in correct position by the lock nut 28. This having been done at room temperature, the unit would then be put in a refrigerator or otherwise have its temperature considerably reduced, say 50 degrees, and the adjusting bolts 24 and 26 would then be moved in and out until the resonant frequency of the circuit at this new temperature was exactly the same as that previously set at the other temperature. This is normally sufficient to provide accurate temperature compensation throughout the entire range of temperatures which may be encountered, although this latter adjustment may be checked and corrected, if necessary, at still a third temperature if desired.

The use of a plate type of thermal or bi-metal strip, with both ends immobilized, results in a very rugged and stable arrangement which does not introduce frequency flutter even under conditions of heavy vibration.

Another form of my invention is illustrated in Figure 5, the inductance element only of the oscillator being shown. Here the coil 50 has cooperating with its opposite ends two cores of such material that they have different permeability and provide, in combination with their respective ends of the coil, different temperature coefficients. Cross members 51 and 52 are rigidly fastened to opposite ends of the coil form 53, the member 51 receiving and supporting a threaded shaft 54 of insulating material, this in turn carrying a core 55; and the member 52 receives a similar threaded shaft 56 carrying a core 57 of different material.

The ordinary powdered iron core, when used in combination with a coil, results in a positive temperature coefficient if the coil was designed to have a zero coefficient without the core, or increases the positive temperature coefficient if the coil already had such a coefficient. Cores available on the open market, made with different metal particles, provide different temperature coefficients, at least one such commercially available core providing a negative temperature coefficient.

I take advantage of this resultant difference in temperature coefficients by association of the coil with different core materials by having the cores 55 and 57 of material providing considerably different temperature coefficients, one providing a temperature coefficient lying to one side to the expected range of adjustment and the other to the other side. If a range about which adjustment was to be desired was in the neighborhood of plus 30, one of these cores should be chosen of material providing a coefficient of about plus 50 with its end of the coil, and the other in the neighborhood of plus 10, for example; while if the desired range was in the neighborhood of zero, one core might be chosen to provide a posi-

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tive temperature coefficient and the other a negative temperature coefficient. Since the cores are independently adjustable, both may be moved in or both out until the desired initial trimming adjustment has been made; then one may be moved in and the other similarly moved out until the temperature compensating adjustment has been achieved. As before, this compensation can be merely for the coil alone, but is preferably a compensation for the entire tank circuit.

The modification of my invention illustrated in Figures 6 to 9 is another form employing a bi-metal strip, the strip 60 in this case being formed in a spiral. The coil 61 again has a core 62 lying therewithin, this core being carried by a shaft 63 of insulating material. In this case the core 62 is eccentrically mounted on the shaft 63, in turn eccentric with the coil 61. Rotational rather than longitudinal movement of the core is used to vary its effect upon the coil, rotation of the shaft centering the core or throwing it considerably off center, as may be best seen in Figure 9.

The shaft is rotatable in an appropriate bushing 64, and has movably mounted thereon a sleeve 65 provided with a slotted tapered outer end adapted to be wedged or jammed into gripping engagement with the shaft 63 by the nut 66. The inner end of the spiral strip 60 is brazed or otherwise fastened to the sleeve 65, and the outer end passes through a slot in a fixed bolt 67. In making the initial adjustment the nut 66 is loosened and the shaft turned slightly one way or the other to effect the trimming adjustment; then the nut 66 is tightened and more or less of the spiral strip 60 pulled through the slot in the bolt 67 to effect adjustment of the compensation coefficient, since this latter action varies the effective length of the bi-metal strip. When the proper compensation coefficient has been attained the nut 68 is tightened down.

While I have described certain embodiments of my invention, it is to be understood that it is capable of many modifications. Changes, therefore, in the construction and arrangement may be made without departing from the spirit and scope of the invention as disclosed in the appended claims.

I claim:

1. In radio communications equipment, apparatus of the character described, including: an impedance assembly having a movable portion; a member having at least a part movable as a function of temperature variations and connected to the movable portion of the impedance assembly for varying the impedance thereof; and means for adjusting the amount of movement of the movable part per unit of temperature variation.

2. Apparatus of the character claimed in claim 1, wherein the movable member comprises a bi-metal strip and the adjusting means comprises means for varying the effective length of the movable part of the strip.

3. In radio communications equipment, apparatus of the character described, including: an impedance element; a cooperating element effecting variation in the impedance of said first mentioned element upon relative movement between said elements; a bi-metal strip for moving one of said elements as a function of temperature variations, the connection between the movable element and the strip being intermediate the ends of the strip; and adjusting means for immobilizing a desired portion of the strip, this

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means being movable toward and away from said connection.

4. Apparatus of the character claimed in claim 3, wherein at least a portion of the strip on each side of said connection is immobilized.

5. In radio communications equipment, apparatus of the character described, including: a tuned circuit having at least one inductive element and one capacitive element therein, one of said elements being tunable and the other element not being tunable in normal use; means movable as a function of temperature variations for varying the reactance of the other elements; and means for readily adjusting the amount of movement of the movable means per unit of temperature variation to enable compensation such that the impedance of the entire circuit remains unchanged during temperature variations.

6. In radio communications equipment, apparatus of the character described, including: a tuned circuit including a variable condenser and a coil; a core adapted to affect the inductance of said coil; and a member carrying the core; a bi-metal strip carrying said member and adapted to move the member and core as a function of temperature variations, the member being movably mounted on said strip to provide a trimming adjustment.

7. Apparatus of the character claimed in claim 6, including means for varying the effective length of the strip to adjust the amount of movement of the core per unit of temperature variation.

8. Apparatus of the character claimed in claim 1, wherein the movable means includes a spiral bi-metal strip and the adjusting means comprises means for varying the effective length of the strip.

9. In radio communications equipment, apparatus of the character described, including: a tuned circuit including a variable condenser and a coil; a core adapted to affect the inductance of said coil; a member carrying the core; a spiral bi-metal strip adapted to move the member and the core as a function of temperature variations; and means for varying the effective length of the strip to adjust the amount of movement of the core per unit of temperature variation.

10. Apparatus of the character claimed in claim 9, wherein the core is eccentrically mounted within the coil and the member and core are rotatable.

11. In radio communications equipment, apparatus of the character described, including: a tuned circuit including a variable condenser and a coil; a powdered metal core adapted to affect the inductance of said coil; a member carrying the core; and a bi-metal plate carrying said member and adapted to move the member and core as a function of temperature variations, the member being movably mounted on said plate at the center thereof, the movement between the member and plate being adapted to provide a trimming adjustment.

12. In radio communications equipment, apparatus of the character described, including an inductive element comprising a cylindrical coil; compensating means operatively associated with said element for affecting the inductance of the element upon temperature variations, said compensating means comprising a rotatable core adapted to affect the inductance of the inductive element, this core being so mounted that its axis of rotation is eccentric with respect to the axis of said coil; and means for adjusting the amount of rotation of said core per unit of tem-

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perature change effecting operation of said compensating means.

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