Sept. 7, 1948. H. M. HUCKLEBERRY 2,448,887

CAPACITOR

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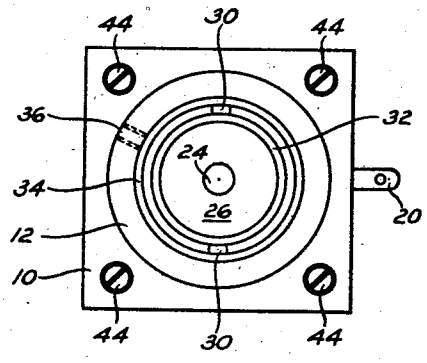


Fig. 1

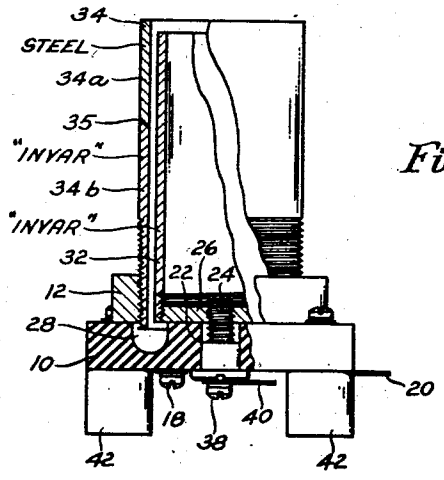


Fig. 2

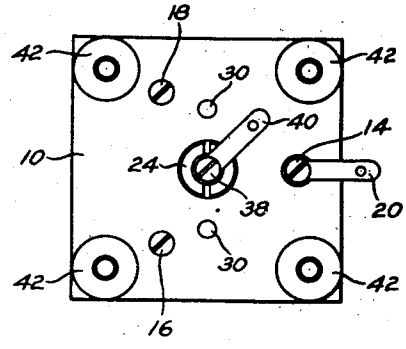


Fig. 3

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CAPACITOR

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6 Claims. (Cl. 175—41)

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This invention relates to capacitors, and more particularly to a capacitor having an adjustable temperature coefficient.

There are many applications in which an extremely stable source of high frequency energy is required, as, for example, in the reception and transmission of radio signals on predetermined channels. In certain classes of equipment it is impossible to employ the very efficient quartz resonator for the purpose of stabilization of the vacuum tube oscillator usually employed, due to the need for continuous tuning over the signal band, forcing the use of inductance-capacitance combinations which afford a more conveniently adjustable frequency determining combination. Arrangements are known whereby the effect of variations in the electrode supply voltages on the operating frequency may be rendered negligible, leaving only the problem of coping with frequency changes produced by various ambient temperatures. These thermally caused changes are generally the result of alterations in the mechanical configuration of the frequency determining elements resulting from their expansion and contraction, and may be minimized by the use of low temperature coefficient materials, or by the use of a compensating element. As the frequency change with increase in temperature is usually negative, compensating capacitors having a negative temperature coefficient have been widely employed, with results which are satisfactory for all but apparatus where high precision is demanded. In these applications, experience has shown that when, in a design, the frequency-temperature coefficient has been reduced to only a few parts per million per degree, irregularities are yet encountered from unit to unit which can only be eliminated from the final product if there is provided a readily and conveniently adjustable compensating unit by which these last few parts per million drift can be eliminated. Though there have been some capacitors having adjustable thermal coefficient by virtue of their connection to a bimetal driving unit, the process of adjustment itself so disturbs the oscillator frequency as to make the precise adjustment of the compensation extremely difficult, if not a practical impossibility. This disadvantage may be overcome if the capacitor whose thermal coefficient is being adjusted is one whose actual capacity is substantially unchanged during the adjustment process.

Accordingly, a principal object of the invention is to provide a new and novel capacitor of substantially constant capacity and having an adjustable temperature coefficient.

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Another object of the invention is to provide a new and novel capacitor whose capacity-temperature coefficient may be smoothly and continuously adjusted by the simple rotation of a control element without alteration of the capacitance thereof.

Other objects and advantages of the invention will in part be disclosed and in part be obvious when the following specification is read in conjunction with the drawings in which:

Figure 1 is a top view of a completed condenser assembly.

Figure 2 is a view in elevation, partially sectioned, of a completed condenser assembly.

Figure 3 is a bottom view of a completed condenser assembly showing the means provided for making connection to the electrodes thereof.

Generally speaking, the apparatus herein described attains the desired objects by the use of two concentrically arranged tubular electrodes, one of which, the outer, is longer than the other. One of the electrodes may be constructed throughout of the same material, while the other, in this case also outer, is constructed of two sections, each having a different thermal coefficient of expansion. The resulting capacitor is composed of two sections, one of which has a negative temperature coefficient, while the other has a positive coefficient, so that by adjusting the position of the outer electrode to bring more or less of one section or the other into play, any desired coefficient may be readily secured; while the capacity does not at the same time change perceptibly so long as the excursions of the outer sleeve do not disengage the inner electrode from its relationship therewith.

Referring now to the drawings there is shown the capacitor base 10, conveniently fabricated of any of the many well known dielectrics, such as steatite, laminated phenolic, and the like, to which the internally threaded ring 12 is secured by the three screws 14, 16 and 18 passing through the base 10 from the bottom, and most clearly seen in Figure 3. A connecting lug 20 is located under the head of the screw 14 to afford a means of establishing electrical connection between an external wire lead, the ring 12 and any object in contact therewith through the body of screw 14. Centrally located in the base 10 is an aperture 22 through which passes a retaining bolt 24 threadedly engaging an aperture in the center of metallic disc 26 having a threaded periphery. An annular groove 28 is machined into the upper

surface of the base 10 and located substantially concentrically with respect to the central aperture 22. The groove 28 is of such width and located at such distance from the central aperture 22 that the internal surface of the ring 12 and the periphery of the disc 26 project thereover. The depth of groove 28 is determined by the intended travel of the outer capacitor plate, as will hereafter be made clear. To prevent the possible collection of fluids in the groove 28 after the completion of the capacitor assembly, two drain apertures 30 extend through to the base of the groove from the bottom of the mounting base 10 as seen in Figures 1 and 3.

A tubular electrode 32, which may be constructed of "Invar" and protected against corrosion by any suitable surface finish, is internally threaded at one end and screwed in place on the disc 26 to serve as the inner electrode of the capacitor; and a second tubular electrode 34 is externally threaded and screwed into place within the ring 12 to form the outer plate of the capacitor. The outer electrode 34 has a length greater than that of the inner electrode 32, which permits relative axial movement between the two without substantial change in the capacitance of the assembly, so long as the inner electrode 32 is completely enclosed by, or in engagement with the outer electrode 34. Outer electrode 34 differs from the inner electrode 32 not only in length, but also in the fact that electrode 34 is a composite structure of two different materials having different thermal expansion coefficients. The upper portion 34*a* may be of steel, while the other section 34*b* is of "Invar," the two tubular sections being joined at the weld line 35. The steel has about ten times the thermal coefficient of expansion of "Invar."

After attachment to the disc 26, the inner electrode 32 may be fixed against further displacement by the use of a cement placed on the threads or about the junction line between disc 26 and the electrode 32. Outer electrode 34 is secured against rotation by the use of the set-screw 36 located in the ring 12. A screw 38 is tapped into the bolt 24 and retains a connecting lug 40 under its head. The inner electrode 32 is thus connectible to the desired external circuits by soldering a lead from the circuit to the lug 40. To permit the mounting of the capacitor assembly on a conducting surface without the necessity for making a cut-out, four stand-off insulators 42 are attached to the corners of the base by the screws 44, the lower portion of these insulators being threaded to receive mounting screws used to secure the assembly to the said surface.

As is well known, the capacitance of a condenser of this nature may be expressed by

$$C=\frac{L\ e}{2\ 1n\ \frac{r_2}{r_1}}$$

where

L is the length of the meshed portion of the electrodes
e is the dielectric constant
r_1 is the outer radius of the inner electrode
r_2 is the inner radius of the outer electrode.

When the radius of the outer electrode increases at a greater rate than that of the inner electrode, as it does in this case within that section of the capacitor formed by "Invar" inner electrode 32 and steel outer electrode section 34*a*, the ratio r_2/r_1 increases with temperature to produce a decrease in the capacitance of the unit. When the radius of both electrodes increases at the same rate, as when they are constructed of materials having identical expansion coefficients, the ratio r_2/r_1 is constant and the resultant capacitance increases due to the change in the length of electrodes. The portion of the capacitor including section 34*b* of the outer electrode formed of "Invar" thus has a positive temperature coefficient. This capacitor, therefore, is composed of two sections having opposite temperature coefficients. Adjustment of the axial position of the outer electrode 34 with respect to that of the inner electrode 32 changes the effective length of each section in opposite sense according as a greater or lesser fraction of the length of the inner electrode 32 meshes with a given section of the outer electrode 34.

This relation motion is effected by loosening the set screw 36 in the ring 12 and rotating the outer tube 34 in one direction or the other, whereby the thread drives the electrode to either bring a larger portion of the inner electrode 32 into engagement with the "Invar" section 34*b* of the outer electrode (upward motion) or to bring a larger portion of the inner electrode 32 into engagement with the steel section 34*a* of the outer electrode (downward motion), depending upon the direction of rotation. Upward motion of the electrode 34 causes the capacitance-temperature coefficient to become more positive, while downward motion of the electrode 34 causes this coefficient to become more negative. The groove 28 in the base 10 is present to permit the necessary travel of the outer electrode 34 which occurs during the adjustment operation, and the operating range of adjustment is controlled so that the entire length of the inner electrode 32 is always in engagement with some portion of the outer electrode 34, whereby the adjustment of the temperature coefficient is without effect on the total capacitance of the unit.

In a practical embodiment of the invention, the electrode 32 had a length of $2\frac{9}{32}$ inches and an outer diameter of 1 inch, while the outer electrode 34 had a length of $2\frac{1}{32}$ inches and an inner diameter of $1\frac{1}{16}$ inch, each being of the materials used for the purpose of illustration in the foregoing description. The resulting structure presented a capacitance of 58 micro-microfarads with a temperature coefficient variable between plus 10 parts per million per degree centigrade and minus 10 parts per million per degree centigrade. It is at once apparent that any metals having different thermal expansion coefficients may be employed in the fabrication of apparatus according to the invention, steel and "Invar" having been employed here solely for illustrative purposes, and also that the inner electrode may be of composite structure rather than the outer electrode, or both electrodes may be composite in structure. In use, it will be found advantageous to connect the outer electrode to the low potential side of the circuit so that changes in its surroundings, as occasioned by the use of the hand for the performance of the adjustment, will have a minimum effect on the unit capacity.

It will be obvious that many changes and modifications may be made in the invention without departing from the spirit thereof as expressed in the foregoing description and in the appended claims.

I claim:

1. A capacitor comprising, a first cylindrical electrode of conductive material, a second cylin-

drical electrode constructed for a portion of its length from a first conductive material having one thermal expansion coefficient and for the remainder of its length from a second conductive material having a different thermal expansion coefficient, one of said electrodes being surrounded by the other, said second electrode being greater in length than said first electrode, means for concentrically supporting said cylindrical electrodes and adjusting the ratio between the area of said second electrode of said first material and the area of said second electrode of said second material in register with said first electrode, and means for making electrical connection to each of said electrodes.

2. A capacitor comprising, a first cylindrical electrode, a second cylindrical electrode constructed for a portion of its length from a first conductive material having one coefficient of response to variations in a predetermined condition and for the remainder of its length from a second conductive material having a different coefficient of response to variations in said condition, said second electrode being greater in length than said first electrode, means for concentrically supporting said cylindrical electrodes so that one surrounds the other and adjusting the ratio between the area of said second electrode of said first material and the area of said second electrode of said second material in register with said first electrode, and means for making electrical connection to each of said electrodes.

3. A capacitor comprising, a first electrode, a second electrode surrounding said first electrode and extending substantially beyond said first electrode in one dimension, said second electrode being constructed for a portion of its length measured in said one dimension from conductive material having one coefficient of response to variations in a predetermined condition and for the remainder of its length from conductive material having a different coefficient of response to variations in said condition, support means for said electrodes permitting adjustment of their relative positions in said one dimension, and means for making electrical connection to each of said electrodes.

4. A capacitor comprising, a base of insulating material, a first electrode having a cylindrical outer surface carried by said base, a second electrode having an inner surface substantially concentric with, spaced from and surrounding said outer surface and extending beyond said first electrode, said second electrode being constructed for a portion of the length

along the axis of said cylinder from conductive material having one thermal expansion coefficient and for the remainder of its length from conductive material having a different thermal expansion coefficient, means supporting said second electrode and permitting movement of said second electrode along the axis of said cylindrical outer surface and secured to said base, and means for making electrical connection to each of said electrodes.

5. A capacitor comprising, a base of insulating material having an annular groove therein, a first electrode having a cylindrical outer surface carried by said base within said annular groove, an internally threaded ring carried by said base concentric with said cylindrical surface and partially overlapping said groove, and an externally threaded tubular electrode received within said ring and having a length substantially greater than said first electrode, a fraction of the length of said tubular electrode being of material having one thermal expansion coefficient and the remainder thereof of material having a different thermal expansion coefficient.

6. A capacitor comprising, a base of insulating material having an annular groove therein and provided with screw receiving apertures, a first electrode having a cylindrical outer surface secured to said base by a screw situated within one of said apertures, a contact lug engaging said screw, an internally threaded ring secured to said base by screws passing through others of said apertures, said ring being concentric with said cylindrical surface and partially overlapping said groove, a contact lug under the head of one of said ring securing screws, and an externally threaded tubular electrode received within said ring and having a length substantially greater than said first electrode, a fraction of the length of said tubular electrode being of material having one thermal expansion coefficient and the remainder of said length being of material having a different thermal expansion coefficient.

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