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3,195,086

TEMPERATURE COMPENSATED INDUCTOR

Filed May 16, 1962

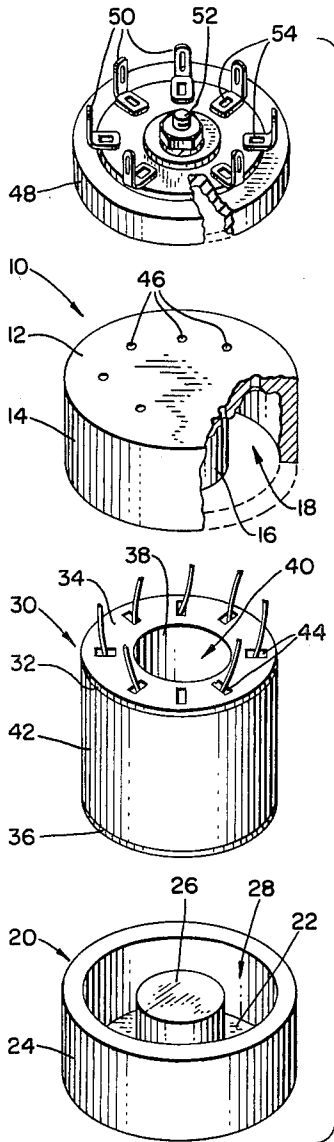


FIG. 1

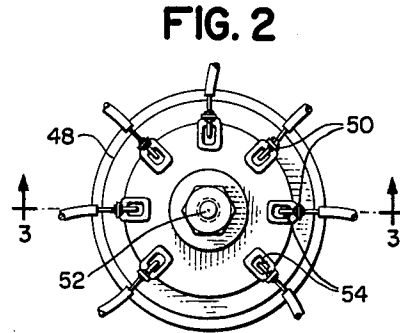


FIG. 2

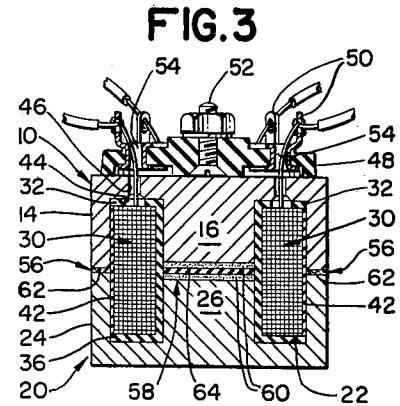


FIG. 3

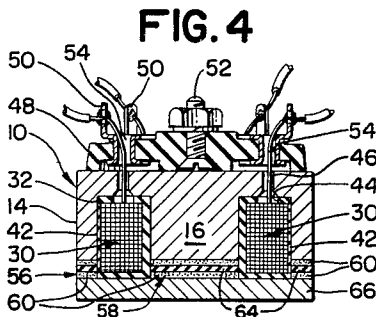
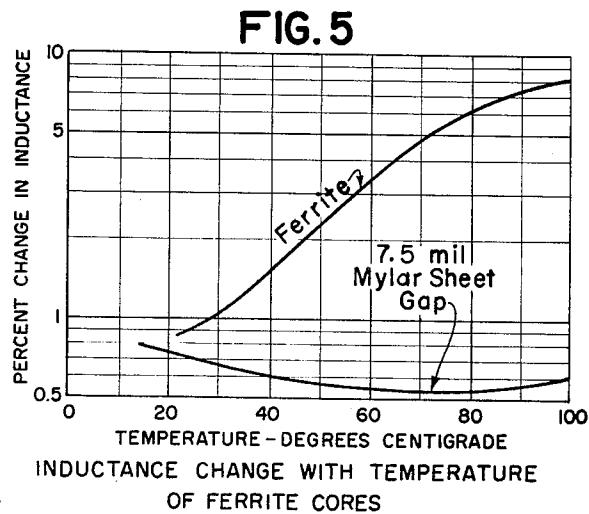


FIG. 4



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3,195,086

TEMPERATURE COMPENSATED INDUCTOR
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3 Claims. (Cl. 336—83)

This invention relates generally to an improved high-Q coil assemblage and more particularly to a temperature compensated coil assemblage which employs a ferrite core. This invention constitutes an improvement over that described in my prior Patent 3,028,570.

Ferrites are ceramic materials made by chemically combining certain metal oxides at high temperatures. A symbolic formula is $MOFe_2O_3$, where M is one or more of a group of metals having about the same atomic size such as magnesium, manganese, iron, cobalt, nickel, copper and zinc. The "M" in common ferrites for audio frequency application consists partly of manganese and partly of zinc. For radio frequency applications M may be part nickel and part zinc. Ferrites, like metallic magnetic materials, have a high magnetic permeability but unlike metals electrical resistivity high enough to provide low eddy current losses. These characteristics of ferrites have led to their adoption as inductance cores providing a high Q or efficiency. When used as coil cores the high electrical resistivity makes unnecessary the insulation between laminations or between core particles as was required by the stacked laminations or compressed powder core materials heretofore used.

However, ferrites have a high temperature coefficient of permeability which at room temperatures may be as high as +1% per degree centigrade. Thus, when used as cores in coil assemblages there will be a considerable variation of coil inductance with temperature change.

It is an object of this invention to provide an improved high Q coil assemblage that will maintain a constant value of inductance over a wide range of temperatures.

It is another object of this invention to provide an improved coil assemblage which has a negligible amount of flux leakage.

It is also an object of this invention to provide an improved coil assemblage which can be mounted easily and quickly to a support member.

It is also another object of this invention to provide an improved coil assemblage which can be easily and quickly adjusted during its manufacture to present a predetermined and constant value of inductance.

It is an additional object of this invention to provide an improved coil assemblage which is reliable in operation and economical to build.

Other subjects and many of the attendant advantages of this invention will be readily appreciated as the apparatus becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is an exploded view of the coil assemblage of the present invention;

FIG. 2 is a top view of the coil assemblage;

FIG. 3 is a section taken on the line 3—3 of FIG. 2;

FIG. 4 illustrates a modified form of structure in accordance with the principles of this invention; and

FIG. 5 is a graph showing the relationship between a coil assemblage built in accordance with the present invention to provide compensation for changes in temperature and an uncompensated coil assemblage.

Similar reference characters refer to similar parts throughout the several views of the drawings.

Briefly, in this invention, a first part of a ferrite magnetic core of a coil assemblage cooperates with a second part of the ferrite magnetic cores to provide through a

first gap and a second gap a continuous magnetic path. A temperature sensitive laminated locking means is interposed within the first gap and coupled to the first and second parts of the ferrite magnetic core to define a gap between the first and second parts of the core which varies with changes in temperature. The second gap can be left as an air gap or filled with a viscous fluid means to close the gap to dirt and still not restrain the movement of the first part of the core relative to the second part. The temperature coefficient of expansion of the temperature sensitive laminated locking means positions the first part of the core relative to the second part of the core to compensate for the temperature coefficient of permeability of the ferrite material by varying the reluctance of the magnetic path through the core assemblage. Leads from the coil are taken out through openings in one end and coupled to a terminal plate which supports electrical terminal projections and a mounting means such as machine screw and nut.

With reference to FIG. 1, a first member 10 composed of ferrite material comprises an end member 12 which supports a cylindrical wall 14 and an internal projection 16 to define therebetween a first annular area 18. A second member 20 also composed of ferrite material comprises an end member 22 which supports a cylindrical wall 24 and an internal projection 26 to define therebetween a second annular area 28. The first and second members 10, 20 are positioned together open-end-to-open-end to form a core member, the first and second annular areas 18, 28 combining to form an enclosed area for accommodating a coil member 30.

The coil assemblage 30 comprises a spool 32 composed of nonconducting and nonmagnetic material having an upper flange 34, connected to a lower flange 36, through a cylindrical member 38 which has a cutout 40. A wire which has two ends is wound onto the spool to form a coil of wire 42. The upper flange 34 of the spool 32 contains a plurality of slots 44 which correspond in number to the leads from the coil 42 which are brought upward through the slotted openings. It is understood that as coil 42 is wound, the various leads other than the end leads are tapped off at points which vary in their radial distance from the center of the coil. It is for this reason that openings 44 are slotted so that the leads can be carried radially in the slotted openings regardless of their radial distance from the coil center to a point directly beneath corresponding core openings 46. In the drawings two of the slots 44 are used for the end leads of the coil of wire 42, and the remaining five slots are used for tap leads.

The dimensions of the coil member 30 are proper to permit it to be positioned within the first annular area 18, the internal projection 16 of the member 10 being positioned within the cutout 40. The end leads and the tap leads of the coil member 30 which appear at the slots 44 are fed through the core openings 46.

A terminal plate 48 that is composed of nonconducting and nonmagnetic material—also referred to as insulating material—supports a plurality of terminals 50, one for each core opening 46, and a centrally positioned mounting member 52 such as a machine screw. Each terminal 50 is secured to the plate 48 by means of a rivet 54 that is positioned within a small opening in the plate 48, and the mounting member 52 is secured by cement or the like to the plate to prevent it from rotating. The terminal plate 48 is secured rigidly to the end member 12 by means of cement or the like, the terminals 50 being aligned with the core openings 46. The end leads and the tap leads from the coil assemblage are passed through the core openings 46 and the associated aligned rivets 54, and are connected to the terminals 50 by means of solder or the like.

To complete the coil assemblage, the lower portion of the core, the second member 20 is positioned within and around the coil member 30—the internal projection 26 being positioned within the cutout 40 of the coil member and the cylindrical wall 24 being positioned around the coil member. The height of the coil member 30 is slightly less than the depth of the first annular area 18 plus the depth of the second annular area 28.

Each of the core sections or members 10, 20 is made of a ferrite material which, as indicated previously, has a high electrical resistivity and a high permeability to provide a coil assemblage having a high Q.

Now, with reference to FIG. 3, the length of the cylindrical walls 14, 24 is greater than the length of the two internal projections 16, 26 to provide two gaps in the magnetic circuit of the core. One gap 56 exists between the ends of the walls, 14, 24 of the cores, and the other gap 58 exists between the ends of the internal projections 16, 26; the gap 56 being more narrow than the gap 58. As will be described hereinafter, the size of the two gaps are determined precisely in order to achieve the improved temperature compensating characteristic.

The gap 56 is made as small as possible to minimize the occurrence of stray flux and the resulting cross-talk which can occur between adjacent assemblages, and to also inhibit the entrance of foreign matter such as dirt to the gap area between the cores and to the area within the coil assemblage.

When assembling, the terminal plate 48 is mounted securely to end member 12 of the first member 10, the openings in the hollow rivets 54 being aligned with the core openings 46. The mounting member 52 of the terminal plate 48 serves as a convenient means for mounting the coil assemblage and the terminals 50 provide easy access to the end terminals and tap terminals of the coil member 30. The coil member 30 is positioned within the first annular area 18 of the first member 10—the upper flange 34 being positioned first within the annular area 18 to permit the leads from the slots 44 to be passed through both the core openings 46 and the aligned hollow rivets 54. The leads are then secured electrically and mechanically to their appropriate terminals 50 by means of solder or the like.

Continuing, the adjacent faces of the internal projections 16, 26 are coated with an adhesive means 60 such as a viscous epoxy cement and the adjacent faces of the cylindrical walls 14, 24 are coated with a viscous fluid means 62. Now a nonmagnetic nonconductive sheet means 64 which is also referred to as an insulating sheet means and having a desired coefficient of expansion is positioned on top of the adhesive means 60 on one of the internal projections 26 and the first member 10 is pressed toward the second member 24 until the desired inductance of the coil assemblage as measured on an inductance indicating bridge network, or the like, is obtained. The insulating sheet means can be composed of material having either a positive coefficient of expansion or a negative coefficient of expansion—the material chosen being determined by the coil assemblage characteristic desired. The coil assemblage is then cured in an oven to polymerize the cement. The viscous fluid means 62 positioned between the end of the cylindrical walls 14, 24 maintains its fluid state—it does not harden. The provision of sheet 64 between thin adhesive layers 60 constitutes an improvement in coil structure over that of my prior Patent 3,028,570, because I can interpose in the gap 58 a material having a negative coefficient of expansion or having a positive coefficient of expansion which is higher or lower than the positive coefficient of expansion of epoxy resin or epoxy resin mixed with magnetic particles described in my prior patent.

Thus, after the curing process there is positioned between the internal projections 16, 26 within the second gap 58 a temperature sensitive laminated locking means

comprising the insulating sheet means sandwiched between layers of the adhesive means 60. One layer of the adhesive means forms a bond between the internal projection 16 and one surface of the insulating sheet means, and the other layer of adhesive means forms a bond between the internal projection 26 and the other surface of the insulating sheet means. It is this temperature-sensitive laminated locking means which secures the first member 10 to the second member 20. The viscous fluid means 62 is used as a filler for the first gap 56 to prevent dirt from being deposited within the gap or entering the interior of the coil assemblage.

Thus, the gap 58 is filled with alternating layers of adhesive means, insulating sheet means, and adhesive means with thicknesses so proportioned that the combined coefficient of expansion of the adhesive means and the insulating sheet means compensate for the temperature coefficient of permeability of the ferrite core over the useful temperature range. The gap 56 must not be filled with an adhesive means as this would restrict the movement of the first member 10 relative to the second member 20. Therefore, the gap 56 is either left as an air-filled gap, or it is preferably filled with a viscous fluid means, such as silicone grease, to prevent dust and dirt particles from depositing within the gap or on the coil and still permit the members 10, 20 to move relative to each other. The provision of a viscous filler which accommodates in thickness to the width of the external air gap 56 without essentially changing the permeability of the air gap is a further improvement over that of my prior patent. In my prior coil structure I use a solid epoxy resin layer having a positive coefficient expansion to fill the external gap, and because it is thinner than the internal epoxy resin layer, it tends to interfere with expansion of the contraction of the epoxy resin layer in the internal gap between the core members. This condition is avoided in my present improved coil structure.

The separation of the first member 10 from the second member 20 at a particular temperature is determined solely by the temperature characteristics of the temperature sensitive laminated locking means. Naturally, the temperature characteristics of the temperature sensitive laminated locking means is determined by the combination of adhesive means and insulating sheet means utilized. Thus, where positive coefficients of expansion are required either nylon or Mylar can be used. However, an insulating sheet means composed of nylon will present characteristics which are different than an insulating sheet means composed of Mylar and, similarly, variations in temperature characteristics will also be obtained by varying the adhesive means used. Additionally, the temperature sensitive laminated locking means can be designed to compensate beyond the normal change which occurs within the ferrite material with changes in temperature to provide an assemblage which has a negative temperature coefficient of inductance.

It is understood that as the surrounding temperature increases, the permeability of the ferrite core increases to increase the inductance of a coil assemblage. However, the temperature sensitive laminated locking means in the gap 58 will vary in size with temperature change—the temperature sensitive laminated locking means increasing in size with increase in temperature to increase the size of the gap 58, and naturally the gap 56, to effect a decrease in the inductance of the coil assemblage. This decrease in inductance eliminates or minimizes the effect of the temperature coefficient of the ferrite material. Thus, the compensating effect of the temperature sensitive laminated locking means provides a coil assemblage which has an inductance that is tailored to be substantially constant or to vary as desired with changes in temperature.

A coil assemblage having a predictably variable inductance can find utility in a timed circuit to compensate for the capacitor's coefficient of capacitor. For exam-

ple, if the temperature sensitive laminated locking means is chosen to over-compensate for the change which occurs within the ferrite material as a result of change of temperatures, then the negative coefficient of inductance obtained can be used to compensate for the positive coefficient of a capacitor associated with the coil assembly in a tuned network. However, if, in a tuned network a capacitor which has a negative coefficient of capacitor such as a capacitor having a polystyrene dielectric is used—then the temperature sensitive laminated locking means is designed to undercompensate for the change which occurs within the ferrite material as a result of change of temperature to compensate for the negative coefficient of the capacitor. In each instance a very stable tuned network will be provided.

With reference to FIG. 4 there is illustrated a modified form of construction in accordance with the principles of this invention. In this instance the second member 20 is replaced with a circular ferrite disc cover plate 66. In this construction a coil member having one-half of the axial lengths of coil member 30 would be used.

In each embodiment, if the gap 56 is made to the same size as the gaps 58, then the temperature sensitive laminated locking means used in gap 58 can also be used in gap 56. This is illustrated in FIG. 4.

FIG. 5 illustrates the change of inductance of an unmodified coil assembly relative to change in temperature; and also a plot of a coil assembly compensated in accordance with the principles of this invention.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An inductor of the character described having a substantially constant inductance over a wide temperature range, comprising a pair of cup-shaped core members formed of a paramagnetic material having a temperature coefficient of permeability of one polarity, each of said core members having an outer cylindrical wall and a central cylindrical, axial projection, said core members being disposed in axial alignment, the central projections being axially aligned with and opposing each other with a circular first gap between facing ends of the central projections and an annular second gap between facing edges of the cylindrical walls, the first gap being wider than the second gap, the wider first gap controlling permeability of said core members while the narrow second gap prevents stray flux leakage beyond said walls, a coil spool having a pair of annular end flanges positioned in a space between said core projections and cylindrical walls, a wire coil wound on said spool, said core members having circumferentially spaced end openings communicating with said space, said end flanges having circumferentially spaced slots registering with said end openings, said coil having a plurality of leads each passing through one of the slots and a registering end opening of a core member, a solid circular sheet of insulation material having a temperature coefficient of permeability opposite in polarity to that of said paramagnetic material over said temperature range, said sheet being disposed between the facing ends of said central projections, and thin layers of adhesive material

bonding opposite surfaces of said sheet to facing ends of said core projections whereby the core members are secured together, the adhesive layers having substantially negligible modifying effect upon the temperature coefficient of permeability of said sheet and core members, said annular second gap containing only air, whereby the temperature coefficients of permeability of said core members and sheet compensate for each other so that the inductance of said inductor remains substantially constant over said temperature range.

2. An inductor of the character described having a substantially constant inductance over a wide temperature range, comprising a pair of cup-shaped core members formed of a paramagnetic material having a temperature coefficient of permeability of one polarity, each of said core members having an outer cylindrical wall and a central cylindrical, axial projection, said core members being disposed in axial alignment, the central projections being axially aligned with and opposing each other with a circular first gap between facing ends of the central projections and an annular second gap between facing edges of the cylindrical walls, the first gap being wider than the second gap, the wider first gap controlling permeability of said core members while the narrower second gap prevents stray flux leakage beyond said walls, a coil spool having a pair of annular end flanges positioned in a space between said core projections and cylindrical walls, a wire coil wound on said spool, said core members having circumferentially spaced end openings communicating with said space, said end flanges having circumferentially spaced slots registering with said end openings, said coil having a plurality of leads each passing through one of the slots and a registering end opening of a core member, a solid circular sheet of insulation material having a temperature coefficient of permeability opposite in polarity to that of said paramagnetic material over said temperature range, said sheet being disposed between the facing ends of said central projections, and thin layers of adhesive material bonding opposite surfaces of said sheet to facing ends of said core projections whereby the core members are secured together, the adhesive layers having substantially negligible modifying effect upon the temperature coefficient of permeability of said sheet and core members, a heat resistant viscous mass filling said second air gap and keeping said second gap filled to exclude dust and air as the second gap changes in width due to expansion and contraction of said core members and sheet at different temperatures over said temperature range, said viscous mass having negligible effect on the temperature coefficients of permeability of said sheet and core members, whereby the temperature coefficients of permeability of said core members and sheet compensate for each other so that the inductance of said inductor remains substantially constant over said temperature range.

3. An inductor according to claim 2, wherein said viscous mass consists of a silicone grease.

References Cited by the Examiner

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LARAMIE E. ASKIN, *Primary Examiner.*

JOHN P. WILDMAN, *Examiner.*

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,195,086

July 13, 1965

Roland C. Taylor

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 75, for "capacitor" read -- capacitance --;
column 5, line 9, for "capacitor", first occurrence, read --
capacitance --.

Signed and sealed this 8th day of March 1966.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

EDWARD J. BRENNER

Commissioner of Patents