April 3, 1962 R. C. TAYLOR 3,028,570

FERRITE INDUCTANCE CORES

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FIG. 1

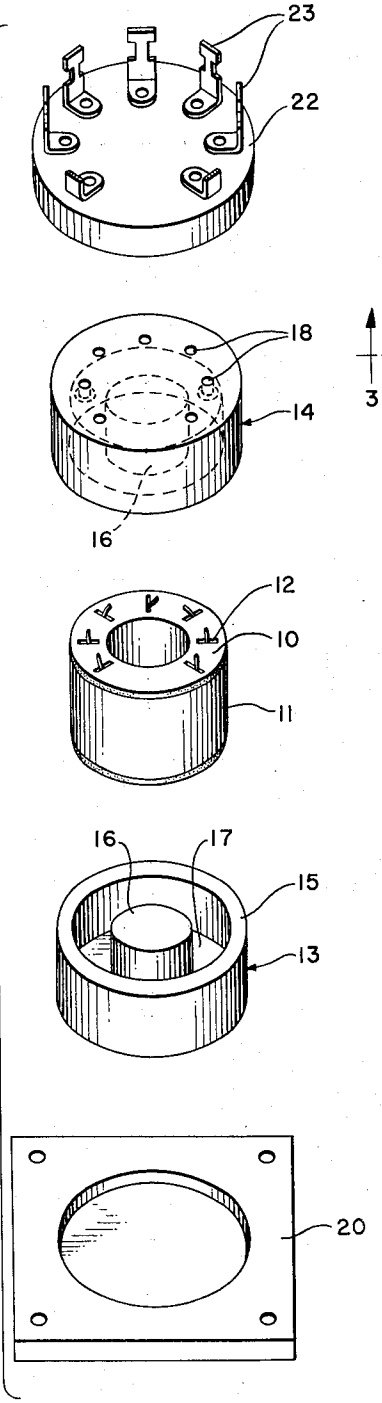


FIG. 2

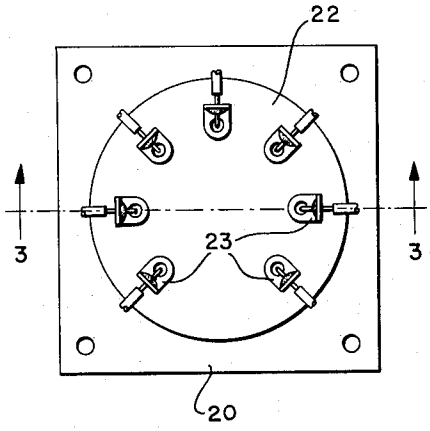
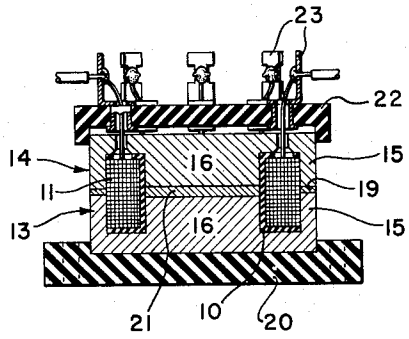


FIG. 3



INVENTOR.
R. C. TAYLOR

BY E. R. Wyche Jr.

ATTORNEY

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FIG. 4

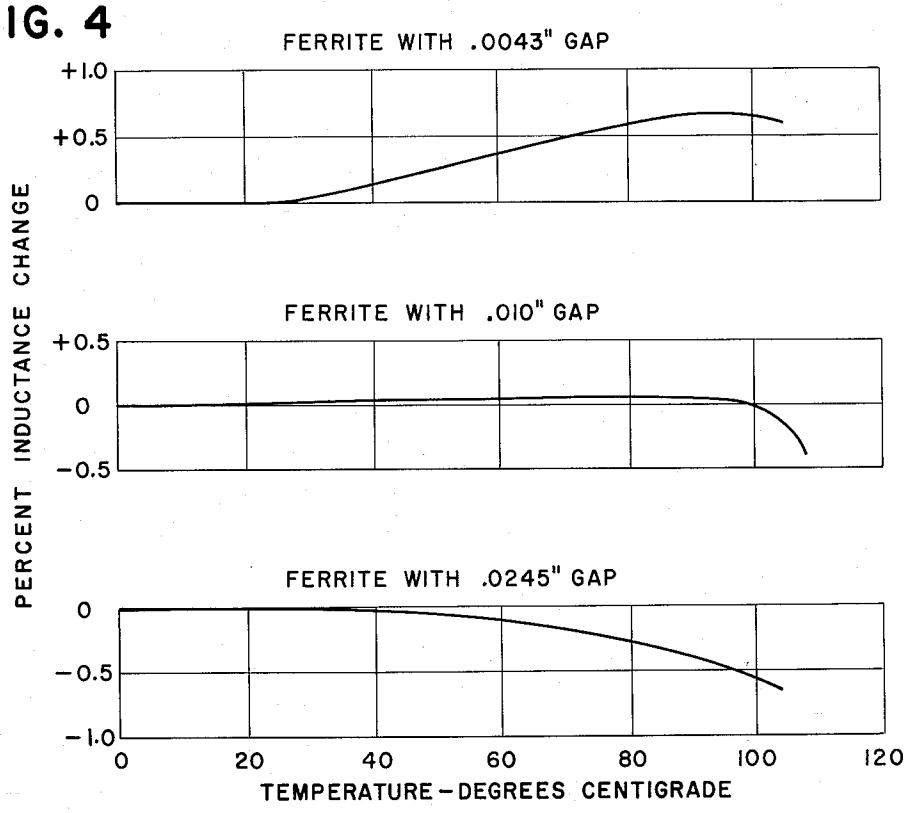
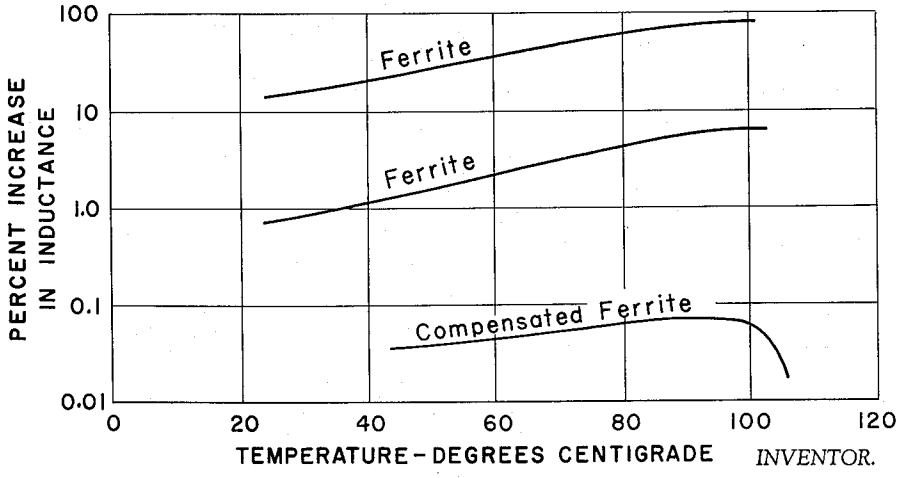


FIG. 5



INVENTOR.
R. C. TAYLOR

BY

ATTORNEY

United States Patent Office

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FERRITE INDUCTANCE CORES

Roland C. Taylor, Ridgewood, N.J., assignor to The Western Union Telegraph Company, New York, N.Y., a corporation of New York

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The present invention relates to coils for inductances and transformers, and more particularly to such coils employing ferrite cores.

As is well known, ferrites are ceramic materials made by chemically combining certain metal oxides at high temperatures. A symbolic formula is $MOFe_2O_3$ where M stands for one or more of a group of metals having about the same atomic size. Examples of these metals are magnesium, manganese, iron, cobalt, nickel, copper and zinc. Common ferrites for audio frequency application have M partly manganese and partly zinc. For radio frequency applications M may be part nickel and part zinc. Ferrites like metallic magnetic materials have 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 that 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 inductance coils, there is a considerable variation of inductance with temperature change. This is one of the primary problems to which the present invention is directed.

Accordingly, a primary object of the present invention is to provide an improved transformer or inductance coil.

Another object of the present invention is to provide a coil having a ferrite core wherein instability due to temperature change is compensated.

Another object of the present invention is to provide a coil employing a ferrite core wherein the inductance is independent of temperature.

A further object of the present invention is to provide a two-part shell type core bound together with a material providing temperature compensation.

A still further object of the present invention is to provide a core assembly which is readily and conveniently constructed.

In accordance with these and other objects, the present invention contemplates a shell type core of two sections which are bonded together by a material such as epoxy resin which has such a temperature coefficient of expansion as to compensate for the temperature coefficient of permeability of the ferrite material. A spool with the coil of wire wound thereon is received within the two-part shell core and leads from the coil are taken out through slotted openings in one end of the spool. A head section having a plurality of terminal lugs is secured to the upper end of the assembly and the coil leads are joined to these lugs. The assembly is completed by a base plate which serves as a convenient means to mount the assembly.

The invention will be more fully understood from the following description of a specific embodiment thereof taken with the drawings in which:

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

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

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

FIG. 4 is a set of curves showing the relationship between the inductance change and temperature for coils having different gaps; and

FIG. 5 is a graph showing the relationship between a coil compensated in accordance with the present invention and uncompensated ferrite material.

Referring now to the drawings, numeral **10** represents a spool which may be made of any convenient material. A coil of wire **11** having a plurality of leads is wound around the spool **10**. The upper flange of the spool has a plurality of slots **12** corresponding in number to the leads from the coil **11** which are brought upward through the slotted openings. It is understood that as coil **11** is wound, the various 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 **12** 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 opening **18**.

The shell type core is made of a lower section **13** and an upper section **14**, each of which is of similar size and contour. Each part comprises an outer cylindrical wall **15**, a central post **16** and an end disk **17**. The central post **16** has a diameter substantially equal to the opening through the spool **10** so that the spool fits within each core part with adequate clearance. The upper core part **14** has a plurality of openings **18** in the upper end thereof through which the wire leads from the coil pass. Each of the core sections **13** and **14** is made of a ferrite material which, as discussed above, has high electrical resistivity and high permeability to provide a coil with high Q. The height of the cylindrical walls **15** is greater than the length of the central projections **16** of the two parts of the core as more clearly seen in FIG. 3. Two resin filled gaps are provided in the magnetic circuit of the two core sections. One narrow gap **19** exists between the walls **15** of the cores and another wider gap **21** between the ends of the core projections **16**. As will be described hereinafter, these gaps are precisely determined in order to achieve the temperature compensating feature of the invention. It has been found that by increasing the gap **21** between the center projections of the cores, the gap **19** between the ends of the outer walls may thereby be lessened, which minimizes stray flux. A base plate **22**, which serves as a convenient means to mount the coil assembly, is secured to the bottom end of core section **13**. A head piece **22** is similarly secured to the upper end of core section **14**. The head piece has a plurality of holes passing therethrough corresponding to the number of coil leads and a plurality of terminal lugs **23** to which the coil leads and external connections may be soldered.

In assembling the coil, the adjacent core faces are coated with a viscous epoxy cement. The spool winding and the two cores are then assembled and the winding leads connected to an impedance measuring device. The core pieces are then pressed together until the desired inductance is measured and the cores are then cured in an oven to polymerize the cement.

It is understood then that as the surrounding temperature increases, the permeability of the ferrite cores would increase and therefore change the predetermined inductance of an individual coil. However, the epoxy cement in the gaps **19** and **21** will expand to increase the size of the gaps which will tend to decrease the permeability of the coil. It is seen that this will eliminate or minimize the effect of a temperature coefficient of the ferrite material. This compensating feature of the resin filled gaps provides a coil having an inductance which is substantially constant over wide temperature ranges.

One modified construction similar to that above de-

scribed contemplates a single cup-shaped core such as the lower section **13** having a circular ferrite cover plate. In this construction a spool having half the axial length of spool **10** would be used.

FIG. 4 illustrates experimental results obtained from three different cores each with a different air gap. It is seen that as the temperature varies from 0° C. to 100° C. the percent inductive change of the coil is very small and well within the limits for practical use of the coils.

FIG. 5 shows the change of inductance as the temperature varies of two ferric materials alone and also a curve of a coil compensated in accordance with the present invention having an .01" gap.

Although the present invention was described employing epoxy resin as the adhesive to join the core parts, it should be understood that other materials having similar coefficients of expansion could be equally well employed. It has been found that a mixture of epoxy and aluminum oxide gives excellent results. Also, the compensating feature of the present invention is not limited to a shell type core as herein shown but could be equally well used with cores of other shapes.

Although the present invention has been described with respect to a specific embodiment thereof, it is understood that this is not to be considered as limiting the scope of the invention as set forth in the appended claims.

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 ferrite material having a positive temperature coefficient of permeability, each of said core members having an outer cylindrical wall and a central projection, said members being joined together at their open ends with a first gap between the ends of the central projections and a second gap between the edges of the cylindrical walls, the first gap being wider than the second gap, the first gap controlling permeability of said members while the second gap prevents stray flux leakage beyond said walls, a coil spool having a pair of end flanges positioned between said core projections and cylindrical walls, there being a plurality of radially disposed slots in one of said end flanges, a wire coil wound on said spool, said wire coil having a plurality of leads each of which passes through one of said radial slots, said gaps between the core projections and the core walls being filled with a mixture of epoxy resin and magnetic particles having a positive coefficient of expansion whereby the overall inductance of the 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 ferrite material having a positive temperature coefficient of permeability, each of said core members having an outer cylindrical wall and a central projection, said members being joined together at their open ends with a first gap between the ends of the central projections and a second gap between the edges of the cylindrical walls, the cylindrical wall of at least one of said core members extending beyond the end of the central projection thereof whereby the gap between the central projections is wider than the gap between the edges of the cylindrical walls so that the wider first gap controls the permeability of said members while the narrower second gap prevents stray flux leakage outwardly of said members; a coil spool having a pair of end flanges positioned between said core projections and cylindrical walls, there being a plurality of radially disposed slots in one of said end flanges, a wire coil wound on said spool, said wire coil having a plurality of leads each of which passes through one of said radial slots, an adhesive resinous material located in the said gaps between the core projections and the core walls, said adhesive having a positive coefficient of expansion whereby the overall inductance of the coil remains substantially constant over said temperature range.

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