Feb. 22, 1966 A. D. FLAMINIO 3,237,137

ENCAPSULATED TOROIDAL INDUCTOR AND THE LIKE

Filed July 23, 1963

Fig. 1

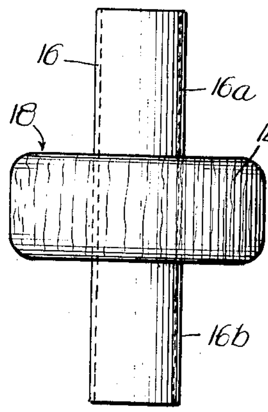


Fig. 3

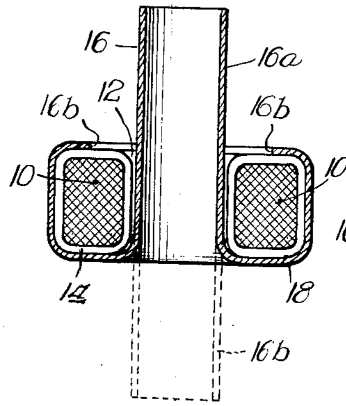


Fig. 5

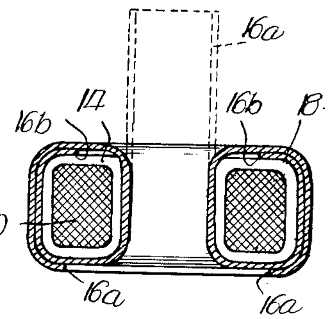


Fig. 2

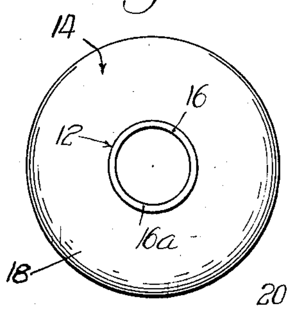


Fig. 4

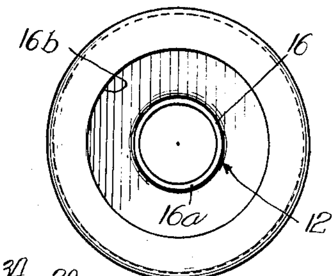


Fig. 6

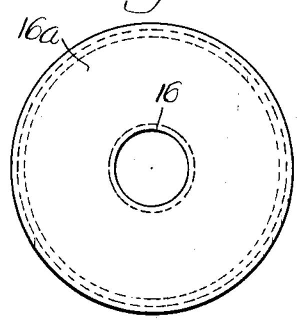


Fig. 8

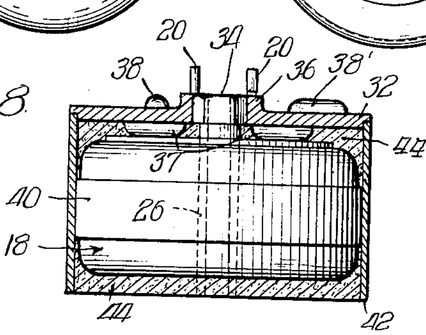


Fig. 7

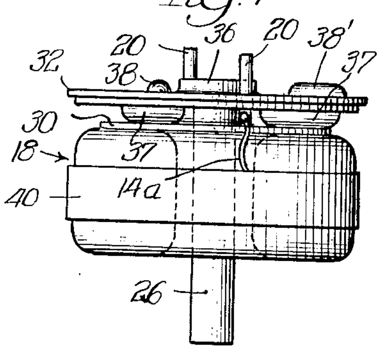
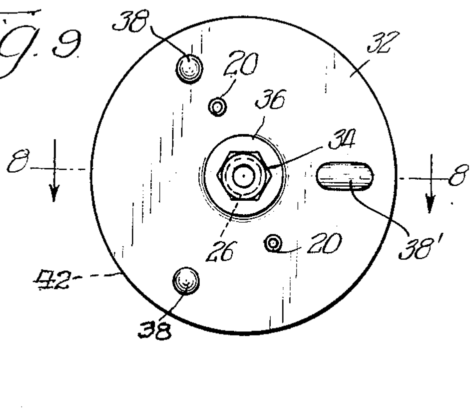


Fig. 9



INVENTOR.
Albert D. Flaminio
BY Brown, Jackson, Boettcher & Dienner
Attys

United States Patent Office
3,237,137
Patented Feb. 22, 1966

3,237,137
ENCAPSULATED TOROIDAL INDUCTOR AND THE LIKE

Albert D. Flaminio, Springfield, Ill., assignor to Sangamo Electric Company, Springfield, Ill., a corporation of Delaware

Filed July 23, 1963, Ser. No. 297,071
6 Claims. (Cl. 336—209)

The present invention relates to encapsulated toroidal inductors and the like.

These toroidal inductors comprise a magnetic core, preferably composed of paramagnetic metallic powders pressed and sintered together in the general form of a ring or doughnut having a central opening therethrough. Wound on this toroidal magnetic core are one or more windings, the turns of which pass successively through the central opening in the core and thence wind spirally outwardly around the surrounding ring structure of the core.

After the completion of the winding operation, the general practice heretofore has been to encapsulate each inductor unit directly into the encapsulating or insulating material. In many instances this results in such material coming into immediate contact with the individual turns of the winding, and also coming into direct contact with exposed portions of the pressed powder core structure. Otherwise stated, there is frequently a complete penetration by the encapsulating or potting material into the minute spaces between the turns of the windings, and also into the minute spaces between the turns of the winding and the surface of the pressed powder core structure. This generally results in objectionable increases in distributed capacitance, in objectionable variations in change of temperature coefficients, and in objectionable mechanical strain on the core which causes a further undesirable shift in inductance, and an undesirable increase in core losses.

I have avoided these objections by employing a unique form of rubber boot which is operative to envelop the entire assembly of the toroidal core ring and the windings wound thereon, before such assembly is contacted by the encapsulating material in the encapsulating operation. This unique form of rubber boot is preferably a cylindrical rubber tube which is inserted into the central opening in the core structure and winding assembly, which insertion occurs after the winding or windings have been wound through such central opening. As originally inserted, this rubber tube has projecting upper and lower ends extending outwardly above and below the top and bottom surfaces of the core structure and winding assembly. One of the projecting ends of this rubber tube—let us say the lower end—is then stretched outwardly to a substantial degree, sufficient to permit this stretched lower end to be doubled back up over the outer peripheral surface of the winding on the core structure. Following this, the other or upper projecting end of the rubber tube is similarly stretched outwardly to a substantial degree, sufficient to permit this stretched upper end to be pushed or doubled back down over the stretched lower end of the rubber tube, whereby the stretched upper end envelops or laps down over the stretched lower end of the rubber tube. The high elasticity of the rubber tube insures that the lapped joint between the upper and lower ends will effectively exclude the encapsulating material in the subsequent encapsulating operation, so that there is no permeation of the material into the small spaces between the winding and the core, or into the spaces between the turns of the winding. The high elasticity of the rubber tube or boot results in another advantage when the units are encapsulated in a vacuum casting technique. In the performance of such method, the overlapped ends of the

rubber boot act as an escape valve for permitting entrapped air to escape during the vacuum casting operation, but tightly seal and prevent the epoxy or other encapsulating material from thereafter entering the space between the turns of wire, thereby resulting in a void-free envelope or cast encapsulation. A still further advantage of the rubber boot is that by excluding the epoxy from the spaces between the turns of the winding, the winding itself absorbs the strain due to the shrinkage of the epoxy, which strain can be very large.

Other objects, features and advantages of the invention will be apparent from the following detailed description of one preferred embodiment thereof. In the accompanying drawings illustrating such embodiment:

FIGURE 1 is a side elevational view of the completed assembly of core structure and winding, showing the rubber tube or boot extending down through the central opening thereof, preliminary to the stretching and folding operations;

FIGURE 2 is a plan view of FIGURE 1;

FIGURE 3 is a transverse sectional view through the core and winding assembly and through the rubber tube, this view showing the first step of stretching outwardly the projecting lower end of the tube and doubling this stretched end backwardly and upwardly so as to have it envelop the outer periphery of the coil;

FIGURE 4 is a plan view of FIGURE 3;

FIGURE 5 is a transverse sectional view similar to FIGURE 3, but showing the next step of stretching outwardly the projecting upper end of the rubber tube and folding this stretched end downwardly over the coil, and over the enveloping lower end of the rubber tube;

FIGURE 6 is the plan view of FIGURE 5;

FIGURE 7 illustrates a preliminary step of connecting the winding leads to the external pin terminals, etc;

FIGURE 8 is a transverse sectional view illustrating in section the encapsulating outer cover for the inductor unit, corresponding to a section taken on the plane of the line 8—8 of FIGURE 9; and

FIGURE 9 is a plan view of FIGURE 8.

Referring first to FIGURES 3 and 5, the toroidal core composed of pressed powder is indicated at **10**, and the central opening extending therethrough is indicated at **12**. Wound spirally around the toroidal ring **10** and through such central opening **12** is the coil or winding portion **14** of the unit. In the case of a simple inductor unit, this winding portion consists of a single winding having two end terminals, and possibly having one or more intermediate taps. In the case of a transformer type of unit, this winding portion would consist of the primary and secondary windings of the transformer.

After the winding portion **14** has been completely wound on the core **10**, the rubber tube or boot **16** is passed down into or through the central opening **12**, in approximately the relationship shown in FIGURES 1 and 2 of the drawings. This rubber tube or boot **16** consists of a natural rubber or a synthetic rubber, preferably of a composition having a very high degree of elasticity so that the boot is capable of being stretched to dimensions several times its original dimensions. Also, this rubber can be very thin, since it serves merely as a skin-tight protecting or covering membrane over the core-winding assembly, the latter being designated **18** in its entirety.

The length of the rubber boot **16** is such that the projecting upper and lower ends **16*a*** and **16*b*** are sufficiently long to produce a substantial degree of overlap between these ends when they are stretched outwardly and caused to envelope the core-winding assembly **18**, as illustrated in FIGURES 5–6. The stretching and enveloping operation can be started at either end; FIGURES 3–4 showing it as starting with the lower end **16*b***. This lower end is stretched or belled outwardly and then pulled upwardly to have it envelope the major portion of the core-winding assembly in a direction from the bottom-side upwardly. In the exemplary proportions illustrated in FIGURE 3, this stretched end **16*b*** is sufficiently long to enable its end edge or extremity to be stretched part way across the top of the core-winding assembly **18**.

This operation is then repeated with respect to the upper end or leg **16*a***, which is stretched or belled outwardly and is then pulled downwardly to have it envelope the major portion of the core-winding assembly, in a direction from the top side downwardly. As described above of the lower end, the end edge or extremity of this upper end **16*a*** extends part way across the bottom surface of the core-winding assembly **18**.

The extremely tight cohesive overlap of the upper and lower ends **16*a*** and **16*b*** establishes a hermetic seal for the boot against the entrance of encapsulating material, air or any foreign matter from the outside to the inside. The conductor ends **14*a*, 14*b***, etc. leading from the winding or windings **14** are extended outside of the finished boot for connection to terminals **20** projecting from the encapsulating shell.

In FIGURE 7 I have illustrated the intermediate step of connecting the conductor ends **14*a*, 14*b*** to the external terminal pins **20**, and preparing the unit for encapsulation. The unit is assembled over a tubular insert or stem **26**, preferably composed of brass and provided with internal threads for receiving a machine screw. A washer **30** is assembled over the insert **26** at one end of the boot covered core-winding assembly. The coil ends or leads **14*a*, 14*b*** are brought over the outside diameter of the washer **30** and are then soldered to the terminal pins **20**.

The terminal pins **20** have anchored mounting in a disk-like base **32** of plastic, which is attached to the end of the stem **26** in spaced relation from the washer **30**. This attachment is preferably effected through a nut **34** which is moulded in a raised control boss **36** and which has threaded engagement or like attachment over a reduced end of the stem **26**. Inwardly projecting spacer humps **37** formed integral with the mounting disk **32** space the washer **30** and core-winding assembly **18** from the base mounting disk **32**. Also, the outer face of the base mounting disk **32** has outwardly projecting spacer humps **38, 38′**. If desired, one lap of tape **40** may be wrapped around the core-winding assembly **18**, but this is purely optional.

The resulting unit assembly is then inserted into a thin cylindrical shell or sleeve **42** composed of Bakelite or other suitable plastic, and the disk-like mounting base **32** is then cemented to the end of the shell **42**. Thereupon the assembly is subjected to the encapsulating operation, with the epoxy or other encapsulating material **44** filling the shell **42** and completely covering all surfaces of the core-winding assembly **18** in contact with the rubber boot **16**. Following this, the open end of the shell **42**, the epoxy material **44** therein, and the projecting end of the tubular stem **26** are then faced off to establish the desired length, and also to form a finished top surface on which can be imprinted the technical data regarding the inductance, etc. of the unit.

The use of the above described rubber boot **16** affords several advantages, some of which have been briefly mentioned before. For example, the rubber boot results in a sealing covering over the core-winding assembly **18** which avoids pin holing, non-uniformity of thickness, and which can still be of a very thin, membrane-like thickness. A further advantage arises in a vacuum casting type of encapsulation. The overlapping ends **16*a*, 16*b*** of the boot act very much as a valve and permit the entrapped air to escape during the evacuation, but seal and prevent the epoxy or other encapsulating material from entering the space between the turns of wire. This produces a void-free envelope or cast encapsulation. The rubber boot covering **16** also lends itself well to the transfer molding process of encapsulation.

While I have illustrated and described what I regard to be the preferred embodiment of my invention, nevertheless it will be understood that such is merely exemplary and that numerous modifications and rearrangements may be made therein without departing from the essence of the invention.

I claim:

1. In a toroidal inductance unit, the combination of a toroidal core structure of a magnetic material having a central opening therethrough, a winding wound spirally around said toroidal core structure and passing through said central opening, said core and winding constituting a core-winding assembly, a generally cylindrical enveloping boot of thin, highly elastic material comprising an intermediate portion disposed in said central opening, said boot comprising upper and lower end portions extending from said intermediate portion, said upper end portion enveloping the upper end of said core-winding assembly and extending down over at least a substantial portion of the outer surface thereof including a portion of said spiral winding, said lower end portion enveloping the lower end of said core-winding assembly and extending up over at least a substantial portion of the outer surface thereof and over at least a substantial portion of the lower part of said spiral winding, one of said end portions overlapping the other end portion, and a protective outer shell of insulating material enclosing the core-winding assembly and enveloping boot.

2. The method of constructing an encapsulated toroidal inductance unit, comprising forming a toroidal core-winding assembly by first forming a toroidal core having a central opening therethrough, then coiling a winding encircling said toroidal core and passing it through said central opening, passing a thin, highly elastic, cylindrical rubber boot through the central opening of said toroidal core-winding assembly, said rubber boot having upper and lower ends projecting beyond the top and bottom surfaces of said core-winding assembly, stretching one of said projecting ends outwardly and then doubling it back over the outer peripheral surface of said assembly and of said winding from one direction, stretching the other projecting end outwardly and then doubling it back over the outer peripheral surface of said assembly from the other direction, one of said stretched ends being lapped over the other stretched end whereby said boot completely envelops the core-winding assembly, and then encapsulating the resulting unit in an epoxy compound.

3. In an inductance unit of the class described, the combination of a toroidal magnetic core structure, a winding wound around said core structure to constitute therewith a core-winding assembly, an enveloping boot of highly elastic material having one end passing through the center of said core structure, enveloping a substantial part of the lower peripheral surface of said core-winding assembly including the lower peripheral surfaces of said winding, and having its other end enveloping a substantial part of the upper peripheral surface of said core-winding assembly including the upper peripheral surfaces of said winding, one of said ends overlapping the other end, and a mass of encapsulating material enclosing said core-winding assembly and said enveloping boot, said enveloping boot preventing the mass of encapsulating material from penetrating into the spaces between the turns of said winding and from penetrating into the spaces between said winding and said core structure.

4. In a toroidal inductance unit, the combination of a toroidal magnetic core structure, a winding wound spirally around said toroidal core structure and passing through the central opening in said core structure, said core and winding constituting a core-winding assembly, a highly elastic enveloping boot of generally cylindrical form passing through said central opening, one of the ends of said boot extending over the outer peripheral surface of said core-winding assembly from one direction, the other end

of said boot extending over the outer peripheral surface of said core-winding assembly from the other direction, one of said stretched ends being lapped over the other stretched end whereby the boot completely envelops the core-winding assembly and completely covers the outer surface of said winding, and an outer insulating compound made to completely enclose said core-winding assembly and said boot in an encapsulating operation, the overlapping ends of said rubber boot functioning as a one-way exhaust valve permitting air entrapped between the core structure and the winding and between the turns of said winding to escape outwardly during the encapsulating operation.

5. In a toroidal inductance unit, the combination of a pressed powder toroidal core structure having a central opening therethrough, a winding encircling said toroidal core structure and passing through said central opening, said core and winding together constituting a core-winding assembly, a resilient rubber boot of generally cylindrical form passing through said central opening, one of the ends of said rubber boot extending back to envelop the outer surface of said core structure and also at least a portion of the outer surface of said winding from one direction, the other end of said rubber boot extending back to envelop the outer surface of said core structure and also at least a portion of the outer surface of said winding from the other direction, one of said boot ends overlapping the other end whereby said boot completely envelops the core-winding assembly, a tubular mounting stem passing through said central opening of the core-winding assembly and through the intermediate portion of said boot, a mounting disk secured to one end portion of said stem, terminals projecting outwardly from said mounting disk and electrically connected to said winding, a preformed shell into which said core-winding assembly, rubber boot and stem are inserted, said mounting disk being secured to one end of said shell, and an encapsulating mass of insulating material in the other end of said shell.

6. In an encapsulated electrical inductance unit of the class described, the combination of a magnetic core structure, a winding wound around said core structure to form a core-winding assembly, a protective sheath in the form of a thin, one-piece tube of highly elastic material extending through the center of said core structure and stretched so as to elastically envelop the core-winding assembly with one of the ends of said tube overlapping the other end of the tube, whereby said protective sheath completely envelopes the inside, outside and top and bottom surfaces of said winding, and an encapsulating material encasing said core-winding assembly and said protective sheath, said protective sheath preventing the encapsulating material from penetrating into the spaces between the turns of said winding and from penetrating into the spaces between winding and said core structure in the performance of the encapsulating operation.

References Cited by the Examiner

UNITED STATES PATENTS

2,382,199	6/1942	Brink	336—229 X
2,965,864	12/1960	La Patka et al.	336—192 X
3,162,934	12/1964	Moyers	29—155.57

BERNARD A. GILHEANY, *Primary Examiner.*

JOHN F. BURNS, *Examiner.*

T. J. KOZMA, *Assistant Examiner.*