Aug. 4, 1970 A. R. OECHSLE 3,522,569

MAGNETIC CORE AND COIL ASSEMBLY HAVING A GAP WHICH IS FIXED BY A REINFORCED ADHESIVE LAYER SPANNING THE GAP

Filed July 20, 1967 2 Sheets-Sheet 1

FIG. 1

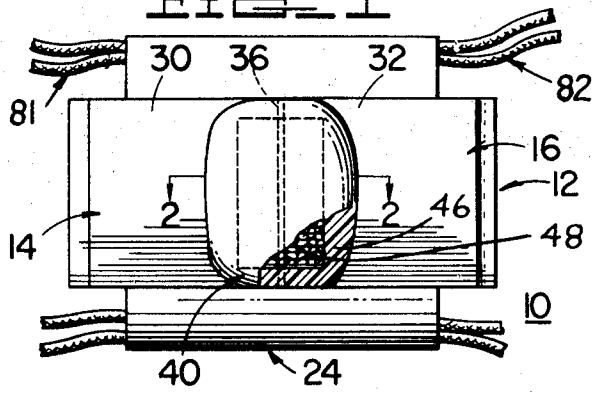


FIG. 2

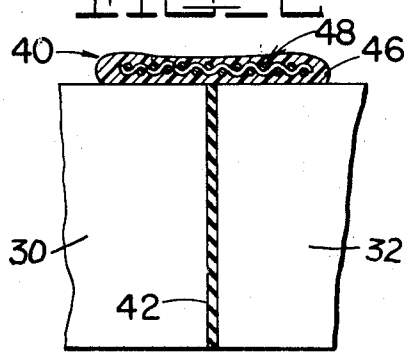


FIG. 3

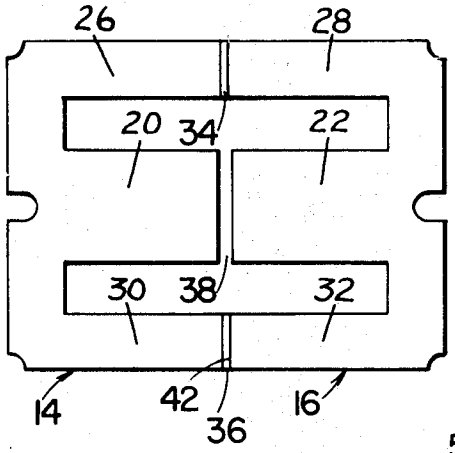


FIG. 4

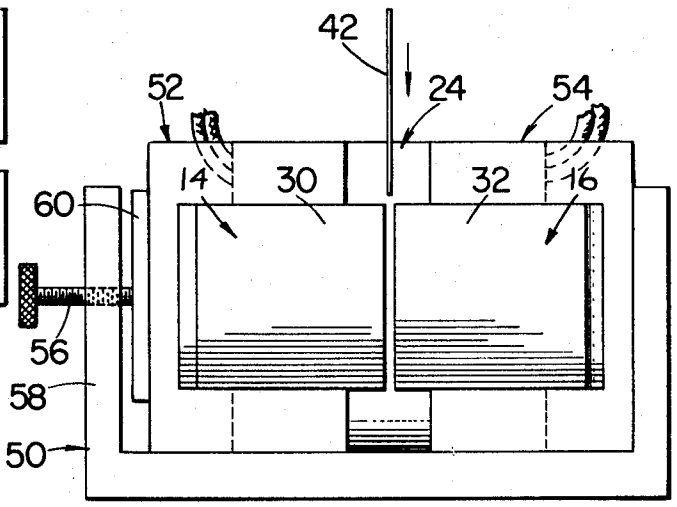
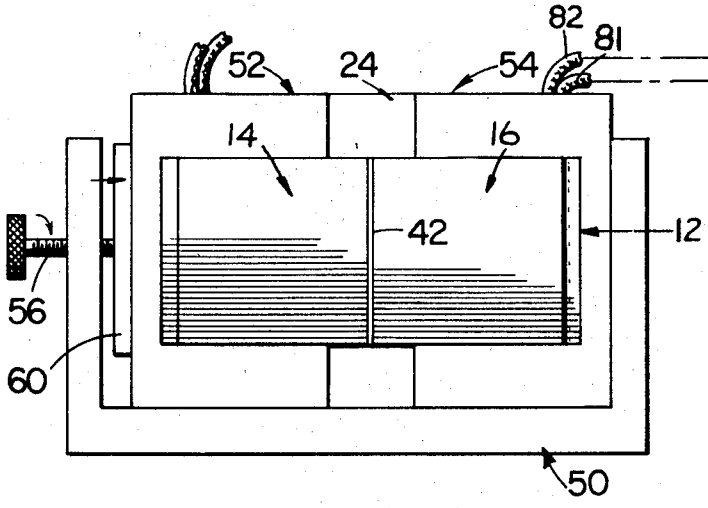
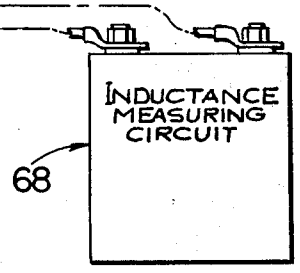


FIG. 5





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FIG. 6

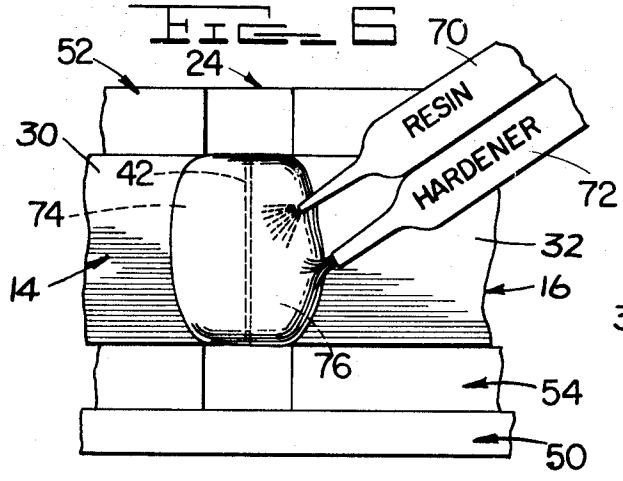


FIG. 7

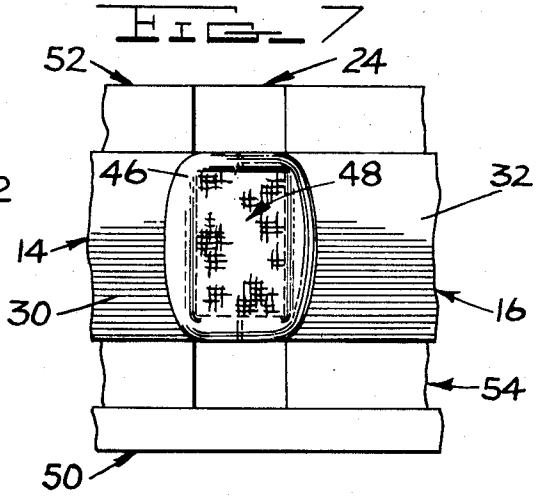


FIG. 8

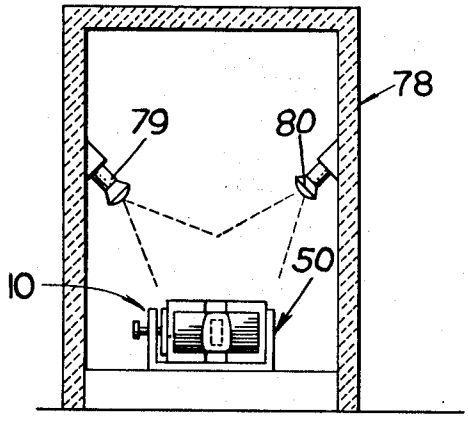


FIG. 9

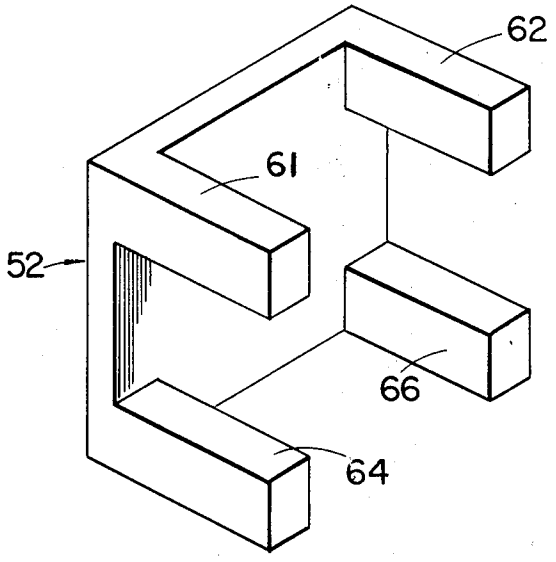
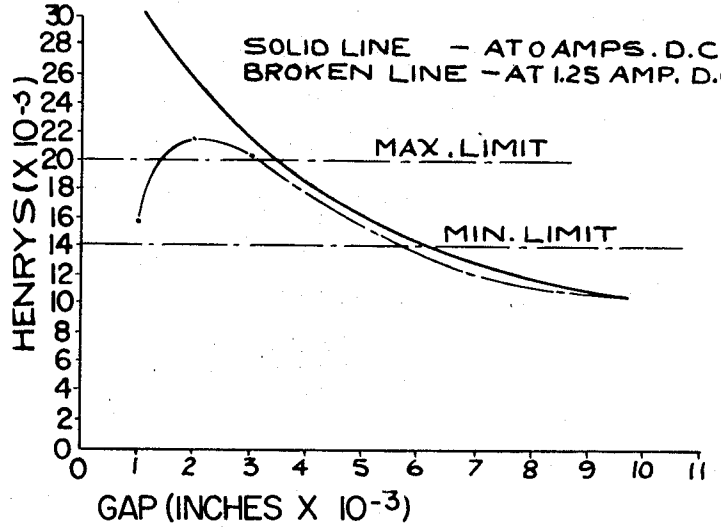


FIG. 10



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MAGNETIC CORE AND COIL ASSEMBLY HAVING A GAP WHICH IS FIXED BY A REINFORCED ADHESIVE LAYER SPANNING THE GAP

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Int. Cl. H01f 21/08, 41/02
U.S. Cl. 336—165 11 Claims

ABSTRACT OF THE DISCLOSURE

Two core sections of an inductive device are held apart by a holding means to maintain gaps of preselected dimensions therebetween during handling and use of the device. The holding means is a layer of adhesive resin material having a perforate screen embedded therein spanning the gaps between the core sections.

BACKGROUND OF THE INVENTION

This invention relates generally to improved inductive devices and methods of fabricating same. More particularly, the invention relates to improved core and coil assemblies having fixed gaps and to methods of fabricating these assemblies with fixed gaps.

Magnetic core and coil assemblies, such as those used in transformers, are often provided with gaps in their magnetic flux paths. One reason for providing these gaps is that under certain circuit conditions the magnetic core may saturate unless there is a gap in the magnetic flux path of the core. Another purpose for such gaps is to match the impedance of the transformer to the remainder of a circuit in which the transformer is being used, as for example when it is desirable to tune the transformer with a circuit capacitor. In any event, it is important that the gap be adjusted within close tolerances and when once fixed, that the gap will be maintained constant during subsequent handling and use of the coil and core assembly.

In certain applications it is possible to mount a core and coil assembly within an elaborate frame or clamping structure in order to fix the core sections in predetermined spaced relation and thereby provide the core with a fixed gap spacing. However, in numerous applications the core and coil assembly is mounted in a case or enclosure wherein size and weight are critical. In these latter applications, it is impossible to use an external frame to fix the gap spacing between two core sections as there is no room in the case for the frame, and it is therefore expedient to use the smallest and lightest possible gap holding means. One approach for fixing gaps of core and coil assemblies is the use of a spacer between the core sections and an adhesive or bonding agent connecting the core sections applied to the surface of the core sections and spanning the gaps. This approach is exemplified in the U.S. patent of H. J. Proxmire, No. 3,114,196.

The spacer-adhesive gap spanning approach, as practiced heretofore, is acceptable when the core and coil assembly is not subjected to rough handling. However, I have found that there is a tendency for the adhesive or bonding agent to crack and break down due to mechanical shocks during rough handling, or when it is vibrated in a case along with other electrical components in an encapsulation procedure such as shown for example in the U.S. patent to J. G. Hoppe, No. 2,938,313. Furthermore, the adhesive agent may crack and the gap spacing be lost due to thermal shocks, as for example during thermal cure of an encapsulation mass. If the spacing of the previously fixed gap is lost, the core and coil assembly must be discarded since the gap spacing is critical to the inductance

of the assembly. Reclamation of such discarded assemblies is difficult if not impossible, as the cured adhesive or bonding material is difficult to remove, and the scrap loss is therefore very high. It is apparent, therefore, that there is a need for a core and coil assembly having a fixed gap spacing which will be maintained constant during rough handling, while adding a minimum amount of bulk and weight to the assembly. It is also apparent that there is a need for a method of fabricating such a core and coil assembly.

Accordingly, it is a general object of the present invention to provide improved inductive devices having fixed gaps, and the method of fabricating such devices.

It is another object of the present invention to provide an improved magnetic core and coil assembly having a gap which is fixed to obtain a predetermined value of inductance, and a method of fixing the gap to maintain it during rough handling and use of the assembly.

It is another object of the present invention to provide an improved magnetic core and coil assembly having a gap holding means between the core sections which is structurally rigid and yet relatively inexpensive to produce.

SUMMARY OF THE INVENTION

In accordance with the invention in one form, I have provided an inductive device including a core having at least two core sections and a coil carried on the sections. Each core section has at least one leg disposed in juxtaposed relation to and spaced from a leg of the other core section to provide a gap therebetween. A gap holding means between the core sections maintains the spacing of the legs to permanently fix the gap spacing, while not projecting unduly far from the outer perimeter of the magnetic core. A non-magnetic spacer may be provided in the gap.

The gap holding means of the exemplification comprises a layer of adhesive material connecting the core sections by spanning the gap therebetween with a reinforcing means embedded in the adhesive layer for reinforcing the adhesive layer. The reinforcing means thereby maintains the structural integrity of the spanning layer during handling of the magnetic core and coil assembly. In a more specific aspect of the invention, the reinforcing means comprises a perforate screen of nonmagnetic material which is substantially surrounded by the adhesive layer.

I have found that the reinforced adhesive layer spanning the gap between the core sections substantially eliminates rejects due to loss of gap spacing while being a relatively inexpensive yet extremely effective means for producing a high quality coil and core assembly. The reinforcing means does not unduly increase the size or weight of the assembly, and the assembly will therefore still fit within the usual cases or enclosures. Furthermore, the improved core and coil assembly constructed in this manner is structurally rigid enough to be used as is, i.e., without the need for an enclosure or any other supporting or frame type structure.

In another aspect of the invention, in one form thereof, I have provided a method of fabricating an inductive device having a fixed gap. The core sections are assembled in a fixture with their legs in juxtaposed relation. A spacer member may then be placed between the legs and the core sections forced together to set the gap spacing. An adhesive means is applied to preselected portions of the core sections, spanning a gap between the core sections, and before the adhesive means has hardened, a reinforcing means is embedded therein. The adhesive means is then cured, hardening into a composite structure which will maintain the spacing of the gap. In a more specific

aspect of the invention, the gap is adjusted by comparing certain electrical characteristics of the core and coil assembly to a predetermined standard, and the adhesive means is a thermo-setting epoxy resin.

The subject matter which I regard as my invention is set forth in the appended claims. The invention itself, however, along with further objects and advantages thereof will be understood by referring to the following descriptions taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational view of a coil and core assembly embodying the present invention in one form;

FIG. 2 is an enlarged partial sectional view taken generally on the plane of the line 2—2 of FIG. 1;

FIG. 3 is a top plan view of the core lamination shown in FIG. 1;

FIG. 4 is an elevational view showing a first step in the fabrication of the core and coil assembly shown in FIGS. 1 and 2, with the core sections being positioned in a fixture and with a non-magnetic spacer being placed between the core sections;

FIG. 5 is a view similar to that of FIG. 4 showing the manner in which the gap spacing is adjusted;

FIG. 6 is a partial view similar to that of FIGS. 4 and 5 showing the next step in the fabrication of the core and coil assembly wherein a layer of thermosetting adhesive material is applied to the core sections;

FIG. 7 is a partial elevational view similar to that of FIG. 6 showing the next step in the fabrication of the coil and core assembly wherein a reinforcing screen is embedded in the adhesive layer;

FIG. 8 illustrates the curing step of the exemplification showing the core and coil assembly after the adhesive layer has been applied and the reinforcing means embedded in the resin, the core and coil assembly being heated in an oven to cure the thermosetting adhesive material;

FIG. 9 is a perspective view illustrating a portion of the exemplified fixture of FIG. 4 used in the fabrication of the core and coil assembly; and

FIG. 10 illustrates the change in inductance of the core and coil assembly of the type illustrated in the various figures of the drawing versus a change in the gap spacing.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1–3 of the drawing, an inductive device or core and coil assembly **10** embodying one form of the invention is illustrated. The inductive device **10** includes a magnetic core **12** comprising two core sections **14** and **16** each of which in the exemplification is comprised of a stack of similar E-shaped laminations. Mounted on the opposed center legs **20** and **22** of the core sections is a coil **24**. The core sections **14** and **16** also include opposed pairs of outer legs **26**, **28** and **30**, **32** with the outer legs being spaced from each other to provide gaps **34** and **36** in the magnetic circuit. The gaps may be provided, for example, to prevent saturation of the core during certain circuit conditions such as an unbalance in direct current, resulting in a net direct current excitation flux. As explained above, the gaps may also be provided to tune the magnetic core and coil assembly with a capacitor in an electrical circuit. An additional gap **38** may be provided between the center legs **20** and **22**. It will be appreciated that the total gap spacing is a determinate of various electrical characteristics of the core and coil assembly **10** such as inductance, and that any variations in the gap will greatly affect these characteristics. Thus, by referring to FIG. 10, it will be seen that at either 0 ampere or 1.25 amperes direct current, a change of only 2 to 3 mils between the core sections of a core generally of the type shown in the various figures will change the inductance characteristics of the assembly **10** beyond predetermined limits. Hence, it is important to maintain the gap spacing constant or nearly constant once it is set.

In order to maintain the gap spacing constant once it has been adjusted and fixed or set, holding means **40** is provided spanning the gaps **34** and **36** between the core sections **14** and **16**. In addition, non-magnetic spacers **42** and **44** are located in the gaps **34** and **36** between the pairs of outer legs **26**, **28** and **30**, **32** respectively. The non-magnetic spacers in the exemplification may be kraft paper, pressed board, or other suitable non-magnetic spacing means. The gap holding means **40** comprises a layer of adhesive material **46**, which in the exemplification is a thermosetting epoxy adhesive composed of an epoxy resin, such as a diglycidyl ether of a bisphenol-A, in combination with a suitable hardener such as an amine. Embedded in the adhesive layer is a plate means generally denoted by numeral **48** for reinforcing the adhesive layer **46** and maintaining the structural integrity of the holding means **40** during handling of the magnetic core and coil assembly **10**. In the exemplification, the plate means comprises a screen which, in actual practice, is a non-magnetic stainless steel wire screen of No. 24 mesh size, having 0.031 of an inch in diameter wire. A non-magnetic reinforcing means is preferable since it will not affect the magnetic characteristics of the magnetic core. However, I have found that by virtue of the relatively small mass of the screen and its relatively great distance from the core, a magnetic material such as tinned steel wire may often be utilized for this purpose without unduly affecting the magnetic characteristics of the core.

While a non-magnetic metallic screen **48** is preferred, other reinforcing means may be used to reinforce the adhesive layer **46**, such as plastic mesh or screen, individual strands of various materials, or other suitable means. In addition, while a perforate or screen type reinforcing means is shown in the drawings and is used in practice, an imperforate metallic or non-metallic plate-like reinforcing means may also be utilized if so desired. When the screen **48** is embedded in the adhesive layer **46**, the adhesive material will flow into the openings in the screen **48** and thereby bond the screen **48** into the layer to form a rigid composite holding means spanning the core sections **14** and **16** across the gaps **34** and **36**. I have determined that it is only necessary for the adhesive layer **46** to substantially surround the reinforcing means for the successful practice of the present invention, i.e., for the adhesive layer to be both above and below the screen **48**.

The inductive device **10**, shown as an exmplification, may be used without additional supporting or clamping means or may be placed in a case (not illustrated) along with other electrical components and encapsulated therein. In either instance, the holding means **40** acts to maintain the previously fixed gap spacing as the screen or reinforcing means **48** maintains the structural integrity of the adhesive layer **46**.

Referring now to FIGS. 4–9 inclusive, an exemplified method in accordance with the present invention is illustrated in connection with the exemplified core and coil assembly **10**. A fixture **50** is used in the embodiment, together with a pair of core section holding members **52** and **54**. The fixture **50** is a C-clamp having a threaded member **56** through one leg **58** thereof for moving a plate **60** inwardly to force or draw the core sections **14** and **16** together during the adjustment of the core gaps (see FIG. 5). The core sections **14** and **16** are mounted in the core holding members **52** and **54**, one of which is shown in FIG. 9 (the holding members are identical, so only member **52** is shown). The holding member **52** has upper and lower pairs of legs **61**, **62** and **64**, **66**. The distance between the upper and lower pairs of legs is precisely dimensioned in order to receive only core stacks of a predetermined height, and the core holding members therefore serve as a measure for stack height, as well as their

primary function of holding the core sections **14** and **16** during assembly or fabrication.

With the core sections **14** and **16** mounted in the holding members **52** and **54**, and with the holding members positioned in the C-clamp **50**, a non-magnetic spacing means **42** may be placed between juxtaposed legs **30** and **32** of the core sections as shown in FIG. 4. It will be appreciated, of course, that another spacer or spacing means is placed between the other pair of juxtaposed legs **26** and **28** of the core sections, which cannot be seen in FIG. 4. It will also be understood that if desired, only the gap **38** between the juxtaposed legs **20** and **22** may be provided, with the outer legs being in contact rather than spaced apart by the spacers. This is possible since the center legs **20** and **22** are shorter than the outer legs. In such case, the step of placing non-magnetic spacers between the jutxaposed outer legs **26, 28** and **30, 32** will not be taken.

Referring now to FIG. 5, it will be seen that the gap spacing in the magnetic core **12** is adjusted by means of a measuring device or circuit **68** with the primary winding connected to the device **68** by the primary leads **81, 82** while the secondary windings, represented by the various other leads, are open. The threaded member **56** is tightened down in order to move the plate **60** inwardly and draw the core sections **14** and **16** together while an electrical characteristic that varies according to the gap spacing is measured. Thus, in the exemplification, the device **68** is an inductance measuring or comparing device, and may be of the type described in the aforementioned Proxmire patent wherein the inductance of the core and coil assembly **10** is measured and compared to a reference inductance. While I have shown in the exemplification the use of an inductance measuring device or circuit **68**, it will be appreciated that other electrical measurements indicative of gap spacing may be made, e.g., by measuring the AC current drawn by the primary with an open-circuit secondary and comparing the measured current to a pedetermined value of current.

The next step in the method is shown in FIG. 6, wherein it will be seen that an adhesive material is applied to portions of the two core sections **14** and **16** in spaced relation to the gaps **34** and **36**. In the exemplification, the adhesive layer **46** is produced as adhesive resin is applied from one tube **70** and a hardener is applied from another tube **72** to portions of the outer faces **74** and **76** of both pairs of juxtaposed legs **30, 32** and **26, 28**, which in the exemplification are spaced apart by the spacers **42, 44** respectively. Before the layer of adhesive material **46** has had a chance to set up or harden, which in the usual case is within one to two hours at room temperature, the reinforcing means in the form of the perforate screen **48** is embedded in the adhesive layer. As shown in FIG. 7, the screen **48** is embedded in the adhesive layer while in an unhardened condition by being laid upon and then pressed downwardly into the adhesive layer **46**, with the adhesive material extruding upwardly through the openings in the screen **48**. It would be possible, of course, to embed the screen in the adhesive layer in other ways, as for example, by applying a first layer of adhesive material at faces **74** and **76**, laying the screen **48** upon this first layer, and then applying a second layer over the screen **48**. This latter method may be preferred when a solid or imperforate reinforcing means is used; however, it has been found that with the perforate screen **48**, the embedding step may be most expeditiously accomplished by pressing the screen **48** downwardly into the adhesive layer **46**.

After the screen **48** has been embedded in the adhesive layer, the core and coil assembly **10**, still in the C-clamp, is placed in a curing oven **78** which may have radiant heaters **79, 80**, if desired (see FIG. 8). With the exemplified adhesive material mentioned above, the cure is accomplished by leaving the coil and core assembly in the oven **78** for approximately 20 to 30 minutes at 125° centigrade. When the cure is completed, the C-clamp is removed from the oven, and the core and coil assembly **10** is removed from the C-clamp. At this time, the holding means **40** is hardened and is in fact bonded to the adjacent or juxtaposed legs of the core sections **14** and **16**, and with the reinforcing means **48** embedded therein provides an extremely mechanically strong or rigid means for holding the core sections together even if the core and coil assembly is subjected to rough handling, vibration, extreme heat, or the like.

While I have illustrated my invention in connection only with one type of core structure, i.e., a laminated core structure composed of two stacks of E-sections, it will be appreciated that the invention is not limited to use with such core constructions. The invention may be used with laminated cores having different lamination configurations, or with unlaminated cores of various designs. In addition, it will be appreciated that the present invention is not limited to maintaining gap spacing between core sections, but may be used whenever a nonmagnetic, lightweight, extremely strong bridging structure is required for holding assembled parts of electrical devices together.

Although I have shown and described herein particular embodiments of my invention, it will be obvious to those skilled in the art that various changes and modifications can be made therein without departing from the invention. Therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An inductive device comprising: a magnetic core having at least two core sections spaced apart to provide at least one gap therebetween; a coil mounted on said at least two core sections; and means for connecting said at least two core sections comprising a layer of cured adhesive resin material applied to adjoining surfaces of said at least two core sections and spanning said at least one gap, and a screen embedded in said layer of adhesive resin material to provide reinforcement therefor whereby said layer of cured adhesive resin material will maintain said at least two core sections in their spaced apart positions during handling and use of the inductive device.

2. The inductive device of claim **1** wherein said layer of adhesive material comprises a cured thermosetting resin, with said reinforcing means being substantially surrounded by said cured thermosetting resin.

3. The inductive device of claim **2** wherein said reinforcing means comprises a perforate screen composed of nonmagnetic material, with said cured thermosetting resin substantially filling the perforations in said screen.

4. The inductive device of claim **1** including spacer means in said gap, said spacer means being comprised of nonmagnetic material.

5. The inductive device of claim **1** wherein each said core section has at least one leg in juxtaposed relation to a leg of other core section to provide said at least one gap therebetween, and said layer of adhesive resin material adhering to juxtaposed legs of each said core section in the vicinity of said gap.

6. An inductive device comprising a magnetic core having at least two core sections and a coil carried on said core, said at least two core sections each having at least one leg being disposed in juxtaposed relation with a leg of the other core section and being spaced therefrom with a gap of a predetermined spacing being provided between said legs, and means for maintaining said legs in the juxtaposed relation thereby to fix the spacing of said gap, said means including a layer of adhesive material spanning said gap, and means embedded in said layer of adhesive material for reinforcing said layer of adhesive material.

7. The inductive device of claim **6** wherein said layer of adhesive material comprises a cured thermosetting

resin, with said reinforcing means being substantially surrounded by said cured thermosetting resin.

8. The inductive device of claim 7 wherein said reinforcing means comprises a perforate screen composed of nonmagnetic material, with said cured thermosetting resin substantially filling the perforations in said screen.

9. The inductive device of claim 6 including spacer means in said gap, said spacer means being comprised of nonmagnetic material.

10. A method of fabricating a magnetic core and coil assembly including a magnetic core having at least two spaced apart core sections and a gap between portions of said at least two sections, the method comprising: assembling the at least two core sections; adjusting the spacing of the gap between the portions of the at least two core sections; applying an adhesive resin layer on the at least two core sections adjacent the gap for joining the at least two core sections; embedding a reinforcing means in the adhesive resin layer; and curing the adhesive resin layer to form a hardened composite joining means connecting the at least two core sections and thereby fixing the spacing of said gap.

11. The method of claim 10 wherein the step of adjusting the gap between the portions of the at least two core sections includes placing a nonmagnetic spacing means between the at least two core sections and moving the at least two core sections toward each other while measuring an electrical characteristic of the magnetic core and coil assembly.

References Cited

UNITED STATES PATENTS

1,763,150	6/1930	Hebrew	336—219 XR
2,055,175	9/1936	Franz	336—139 XR
2,494,180	1/1950	Koubek	336—100
3,238,484	3/1966	Dacey	336—178

FOREIGN PATENTS

6410120 11/1964 Netherlands.

THOMAS J. KOZMA, Primary Examiner

U.S. Cl. X.R.

29—602; 336—178, 219