Sept. 19, 1967 A. E. FEINBERG ET AL 3,341,939

METHOD OF BONDING LAMINATED ELECTROMAGNETIC CORES

Original Filed June 29, 1961

Fig. 1.

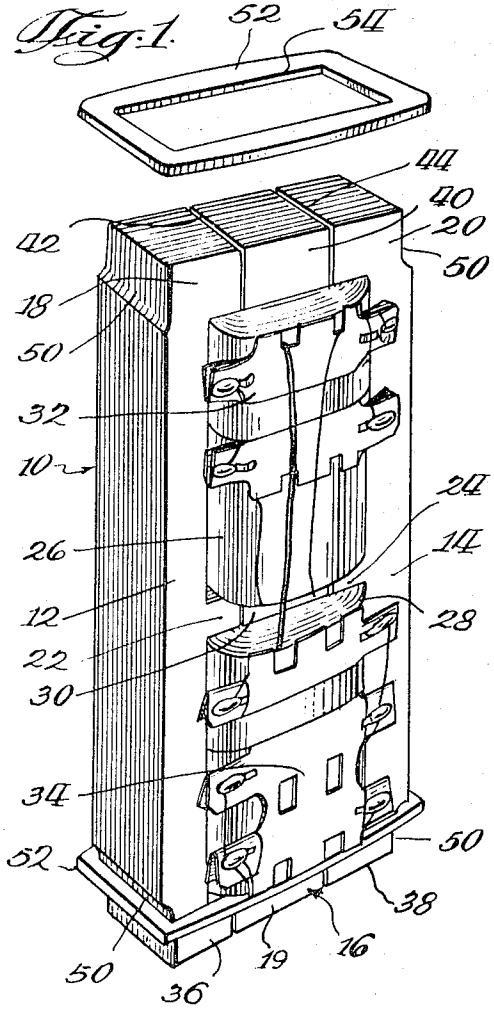


Fig. 2.

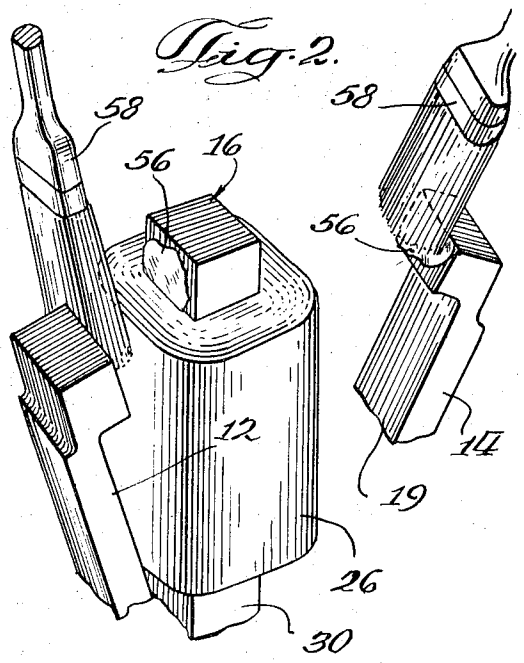


Fig. 3.

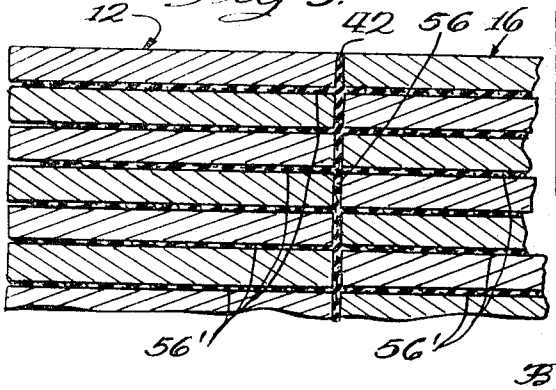
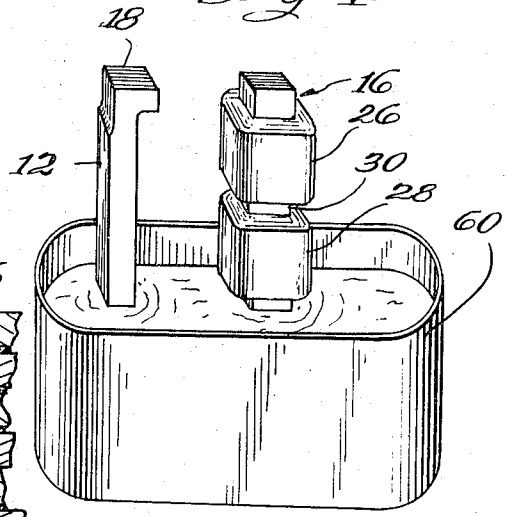


Fig. 4.



INVENTOR.
Albert E. Feinberg
Eugene Czernobil
By Silverman & Cass
attorneys

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METHOD OF BONDING LAMINATED ELECTROMAGNETIC CORES

Albert E. Feinberg and Eugene Czernobil, Chicago, Ill., assignors to Advance Transformer Co., Chicago, Ill., a corporation of Illinois

Original application June 29, 1961, Ser. No. 120,656, now Patent No. 3,222,626, dated Dec. 7, 1965. Divided and this application Aug. 19, 1965, Ser. No. 493,297
7 Claims. (Cl. 29—606)

This application is a division of our copending application, Ser. No. 120,656, filed June 29, 1961, now Patent No. 3,222,626 issued Dec. 7, 1965.

This invention relates generally to the art of manufacturing electromagnetic devices such as transformers, and more particularly is concerned with a method of manufacturing the cores for such devices using cementitious bonding media.

The electromagnetic devices with which this invention is concerned comprise iron cores formed of laminated electrical sheet steel, and having coils or windings mounted thereon. The invention herein evolved as a result of investigations directed towards the production of highly economical ballasts for use in gaseous discharge device circuits, but it is believed that the invention has much broader application.

Many transformers used in ballasts for gaseous discharge device circuits are presently formed as shell structures usually of elongate configuration, having an outer rectangular frame-like portion and a central elongate winding leg extending between the bridged ends of the outer frame-like portion. Windings are mounted on the central winding leg disposed in windows formed between the said central winding leg and the side legs of the outer frame-like portion. Such an assemblage is provided with terminal boards or strips providing electrical terminals for the windings and facilitating the connection of the electromagnetic device into a circuit. The core is rigidly held together, and the entire device is usually encapsulated by a suitable potting compound in a metallic canister along with other elements, such as condensers, resistors, etc., with terminal leads protruding from the canister.

The shell type core is quite popular because in recent years it has been possible to manufacture the same from so-called scrapless laminations as taught, for example, in U.S. Patent No. 2,892,249 and others. Such core is formed of stacks of T and L or T and F laminations instead of being formed of laminations of the type shown, for example, in Feinberg Patent No. 2,558,293. In this patent the shell type core is formed of an integral one-piece outer frame portion having the central winding leg frictionally engaged inside the bridging ends. This is a so-called "forced" core.

The problem which has arisen with respect to so-called scrapless variety of electromagnetic cores is that the core is made up of three elongate metallic members, namely the center winding leg which is usually in the form of a T and the outer portions which are usually in the form of L's or F's. Not only is it required that the stacks of laminations themselves be maintained in assembled condition, but likewise it is necessary that the three core parts be held together in some manner by suitable means.

It has heretofore been customary to use a metallic clamp with spring fingers in the form of a cap secured over each end of the core after the windings have been associated thereon, and by such structure mechanically holding the core in assembly.

The use of metallic clamps has been a source of certain disadvantages, especially the production of noise. It is difficult to manufacture the clamps with such structure as rigidly to hold every one of the laminations immovably.

Variations in dimensions of the laminations result in vibration giving rise to buzzing and humming because of metal contact. There may be many sources for such noise. The stacks of the respective parts may not be the same height; the dimensions of the individual laminations may not be identical; there may be variations in the configuration and resilience of the spring fingers of the clamps; the engagement of the clamps upon the laminations and the laminations upon one another may not be perfect.

Clamps are also quite expensive because they have to be made with highly specialized steels, heat treated for forming spring fingers and using complicated tools and dies. Furthermore, they add to the weight of the ballast. In certain cases, they can cause adverse effects on the magnetic characteristics of a transformer or inductor by providing parasitic paths or undesirable leakage of flux.

The invention herein overcomes all of the objections and disadvantages above enumerated and many others, which will become apparent, by providing a novel method of forming the core for the electromagnetic device using a curable cementitious or adhesive material for bonding the stacks of laminations together, and as well for bonding the respective laminations of each stack one to the other. This comprises an important object of the invention.

The invention has as another object thereof the utilization of a polymerizable resinous material during the formation of a core assembly, said resin's curing or setting cycle is characterized by the presence of an intermediate low viscosity fluid stage to permit said resin to be dispersed, as by capillary action, between each of the laminations of core assembly whereby to serve as a bonding agent therefor in its cured or set state binding all of the laminations in said core assembly into a rigid body, said resin, in its cured state being characterized by high thermal stability.

Still another object of this invention is the provision of a core construction as described above wherein the laminations thereof may be bonded one to the other in a rigid mass to result in a substantial decrease in the noise-forming characteristics of the said core, said bonding agent comprising a polymerizable epoxy resin system which may be temperature or catalytically cured or set and said uncured composition being applied by dipping or brushing onto the edges of said laminations when same are assembled and clamped to form a core construction assembly, said resin being chosen so that a low viscosity intermediate product is formed during the curing or setting thereof thereby introducing, as by capillary action, said bonding agent between the individual laminations, and completing the curing or setting of said resin system to form a substantially permanently bonded unit which remains rigid during subsequent conditions of manufacture and operation.

Still a further object of the invention is the use of a novel clamping member, which is formed of an extremely economical material, such as pressed fiberboard or paperboard used for maintaining the ends of the core in assembly while the cementitious material is setting.

A further object of the invention is to provide a method of making the core structure of an electromagnetic device of the type formed with a laminated core and electromagnetic coils mounted thereon in which, during the course of manufacture, a clamp is used to maintain the core in assembly during the course of manufacture but which clamp readily may be removed and discarded after the core has become a bonded integral structure.

Other objects of the invention will occur to those skilled in this art as a description of the invention herein proceeds, in connection with which the drawings illustrate preferred methods of making the core structure of an electromagnetic device.

In the drawings:

FIG. 1 is a perspective view of an electromagnetic apparatus consisting of a transformer for use in a fluoroscent lamp circuit which has been constructed in accordance with the invention, but the same being illustrated with one of the clamps of the invention disposed in exploded relation to an end of the core.

FIG. 2 is a diagrammatic perspective view showing a method of applying the thermo-setting resinous material to the parts of the transformer core shown in FIG. 1.

FIG. 3 is an exaggerated sectional view showing the manner in which the cementitious material penetrates into the core while it is curing.

FIG. 4 is a diagrammatic perspective view showing another method of applying the cementitious material to the core.

The invention is based in part upon a discovery that certain polymerizable resins having epoxy, polyurethane or equivalent based constituents which are available on the market have unusual bonding powers of sufficient degree to retain steel laminations in assembly. In the shell type of core which utilizes a plurality of core members which must be held together, such resins applied to the abutting laminated end faces and clamped in this association were found not only to result in a bonding together of the clamped members but as well to penetrate between the laminations and cause the individual laminations to be adhered face to face in a compact unitary structure. In order to hold the ends of the core together during the setting of the resin, the invention contemplates the use of a simple rectangular ring of paperboard or fiberboard readily crushable to enable the variations in the lamination dimensions to be accommodated, but yet having sufficient strength to retain the core in assembly while the resin is curing. Such rings or clamps are extremely economical and obviously can be permitted to remain in place upon the ballast or stripped from the ballast and discarded. Such rings are also highly economical and simple to manufacture by merely stamping the same from sheets of paperboard or fiberboard. In the ensuing description a preferred resin or cement of the epoxy or urethane type will be utilized; however, this is not meant to be a limitation of the scope of the invention to such type resin. Even polyester based resins having tensile strength properties so as to solidly adhere the laminations one to the other may suffice.

Referring now particularly to the drawings, FIG. 1 illustrates a transformer **10** which is made up of three parts, a pair of elongate outer F-shaped legs **12** and **14**, and a center T-shaped leg **16**. Each of these three parts is formed of a stack of laminations, the laminations of each respective part being identical in configuration. Obviously it is intended that each of the stacks be of the same height.

The individual laminations of each stack are held together, generally by rivets, as well known in the art. Notwithstanding their assembly in stacks, it must be understood that the individual laminations of a stack are free to move in small increments within the limits of their riveted connection. Such movement takes the form of vibrations the effect of which is highly undesirable operational noise unless the said freedom of movement is eliminated. This phenomena is one which has faced artisans in this art for many years. It also is possible for an operator manually to grasp tightly a number of laminations in juxtaposed aligned relation to form a "stack" i.e. a core part, of sufficient predetermined thickness, and to handle said separate laminations as a single stack for a rather short limited time. Such last mentioned "stacks" can be hand held during the "dipping" or "brushing" step contemplated by the method of the invention without the laminations falling apart from their stacked grouping. These operations are of momentary duration. Hand-holding and/or riveting are well known in the art of manufacturing electromagnetic core and coil assemblies and would be inherently understood by the skilled artisan in this art.

As viewed in FIG. 1, the parts **12** and **14** are arranged with their right angle legs **18** and **20** at the upper end of the view, and the intermediate extensions **22** and **24** forming shunts in a manner well known. The center T-shaped leg **16** has its cross-head **18** at the bottom of the view abutted between the lower ends of the respective side parts **12** and **14** while the major portion thereof comprising the central winding leg **30** of the core passes through a pair of windings **26** and **28** disposed on the said central winding leg in windows which are formed in a manner well known. Suitable terminal boards **32** and **34** are held to the windings by means of adhesive tape or the like and the various connections from the windings **26** and **28** are brought out and soldered to the terminals of the terminal boards.

The lower ends of the side members **12** and **14** are identified by the reference numerals **36** and **38** while the upper end of the central winding leg **30** is identified by the reference numeral **40**. It will be seen that in the assembly of the ballast, the legs **18**, **20** and end **40** are disposed in abutting relationship along two junctures **42** and **44** while a similar arrangement is provided at the bottom end of the core due to the abutting relationship of the ends **36**, **19** and **38**.

For the purposes of describing this view, it may be assumed that the junctures **42** and **44** and the equivalent junctures at the bottom of the core have been provided by bonded and cured epoxy or urethane resin, and that the resulting core structure of the transformer **10** is a unitary assemblage, rigid and immovable, not only with respect to the parts **12**, **14** and **16** but as well with respect to the individual laminations making up the parts. In the course of building the ballast, or electromagnetic device, first the central winding leg **30** will have the two windings **26** and **28** assembled thereto by passing the said central winding leg through the centers of the windings into the tubular paper forms upon which the windings are formed. These two windings are adjusted along the length of the central winding leg with one winding such as winding **28** usually abutting against the cross-head **19** of the T and the other winding **26** spaced sufficiently from winding **28** to be accommodated in the windows which will be formed when the parts of the electromagnetic device are assembled. Thereafter the stacks of laminations forming the side parts **12** and **14** are assembled to the central winding leg over the windings **26** and **28** having previously been treated with the cementitious material, such as the epoxy or urethane resin or cement referred to, and the ends are clamped together.

In order to clamp the ends of the electromagnetic device together during the setting of the epoxy or urethane resin or cement, notches such as shown at **50** are provided at the four corners of the core structure. These notches are no different from those heretofore used in electromagnetic devices which utilized metal clamps. In this case, however, instead of metal clamps, rectangular rings **52** are engaged over each end of the electromagnetic device. These rings **52** may be referred to as "disposable binder means" since they may be disposed of subsequent to cure of the resin as hereinafter described. Each ring has a central recess **54** which fits the assembled core ends, the recess being formed at the same time that the rings are stamped. The recess may be formed slightly smaller in its interior dimensions than the maximum dimensions of the ends of the core. The material from which the rings preferably are made is paperboard or fiberboard of some kind which is crushable so that the ring may be forced on to the ends of the core and will tightly hold the portions of the core as well as the laminations in assembled condition without any danger of movement.

It will be appreciated that the strength of the ring need not be sufficient to enable dependence upon such ring for maintaining the ends of the core in assembled condition

permanently without other means being used. The only function required of the rings in this usage thereof is to maintain assembly until the cement has set or cured, and for this purpose the rings are more than sufficient. The exploded portion of FIG. 1 illustrates the manner in which the ring is installed or removed. An arbor press or ram may be used. The rings may be left in place after the core has been formed, and the cement set or cured, or the rings may be removed if it is desired to keep the size of the core as small as possible and eliminate possible pressure points against lead wires. It is immaterial which. Often the adhesive may run onto the ring and thereby prevent its ready removal in which case it may be left in position.

In applying the epoxy or urethane resin or cement to the portions of the electromagnetic device **10**, several different methods may be used. In FIG. 2, the central T-shaped member **16** and the side members **12** and **14** are shown being painted with the adhesive or cementitious material which is designated **56**, on the abutting surfaces, by means of the brushes **58**. There will be two opposite surfaces or end faces of the end of the member **16** and the end faces of each of the side members **12** and **14** respectively. Obviously similar surfaces at the lower end of the core will be painted with the cement.

In FIG. 4, another method is shown in which the entire end of the core member is dipped into a container of the epoxy or urethane resin or cement such as shown at **60**. When this is done, the windings **26** and **28** or any other windings which are intended to be mounted on the central winding leg are already in position. Obviously the stacks must be held together by some suitable means during this process although it is a simple matter for the workman who is assembling the device to hold the stacks of the side members **12** and **14**, for example, in his hand while this is being done and slip the rings **52** over the ends after the core has been assembled.

One property of the resin suitable here such as the urethanes are epoxy resins has been found to be of great advantage. The epoxy cements as they are used today are of rather viscous consistency and do not run rapidly or readily into the interstices between the laminations. Just before the set or cure, however, the physical properties of the epoxy cement undergo a change which renders them very fluid and penetrating. For the purpose of this description the term "low viscosity" is intended to be interpreted as meaning that the material is characterized by a high degree of flowability. High viscosity is intended to reflect a viscous consistency of low flowability. At this point it has been found that the epoxy cement will penetrate between the tightly held adjacent laminations somewhat as shown in the exaggerated view of FIG. 3, and by capillary action during cure the epoxy cement will be drawn to a great extent transversely almost to the very outer ends of the laminations, thereby providing a very strong bond not only between the two portions which are abutted but as well between the face to face surfaces of the individual laminations. Now the degree of freedom of movement of individual laminations can be substantially reduced upon setting of the resins. We also can say that there is a third stage of the resin upon curing where the resin has zero flowability. In FIG. 3, for example, there is illustrated in section the abutting juncture or joint **42** between the side parts **12** and the central part **16**. The epoxy resin or cement **56** provides a bond between the abutting faces of the parts **12** and **16**, and the epoxy resin or cement **56'** which has run between the surfaces of the individual laminations provides the advantageous assembly of the entire apparatus into an integral structure. The epoxy cement is shown in the view in its cured condition by means of the dark areas between laminations.

It is feasible to use some manner of flexible or extensible member other than the paperboard or fiberboard ring **52** to hold the ends of the core in assembled condition while the epoxy resin or cement is curing. It is preferable that such a member have the property of being able to apply fairly even pressure upon each and every lamination of the assemblage, so that when the cure occurs, there will be no misplaced laminations or air spaces. It is believed that there has been no successful bonding of the ends of electromagnetic devices comprising laminated cores with such thermo-setting resins.

It is also desired to point out that other cementitious or bonding materials may be used advantageously with the rings **52** and that after such cementitious materials have set, the entire assemblage **10** may be impregnated with varnish and baked and/or encapsulated in some plastic or potting compound, thereby adding overall rigidity to the assemblage and relieving some of the strain from the rings **52**. Under such conditions, of course, it is intended that the rings will remain in position on the completed electromagnetic device.

The retaining rings **52** instead of being made of paperboard and fiberboard may in ceertain instances be of a semi-permanent nature, being made of synthetic resins, such as nylon or other plastics, which while to some extent yieldable nevertheless have great strength. The yieldability, on the interior of the ring at least, is to accommodate variations in stock size and lamination dimensions. Whether of paperboard, fiberboard or plastic, the ring should be able to withstand the temperatures to which the electromagnetic device may be subjected before the adhesive has set or is cured.

In using the method of the invention, the curing of the cementitious or resinous material may take place in several ways. It may be permitted to take place in air; it may be accelerated by baking in an oven; it may occur as a result of "potting" with no potting compound; it may occur simultaneously with another procedure such as varnishing and/or baking the varnish.

Although many resins are suitable for use with the invention, it is preferred to utilize those of the group epichlorohydrin bisphenol-A which has been catalyzed by an acid anhydride. To speed the curing or setting of the resin system, a small amount of an accelerator may be added, such as for example, a tertiary amine, or commercially available dimethylamino methyl-phenol, tridimethyl amino methyl phenol, and the like.

An exemplary formulation was successfully utilized to prepare a core of the character described. Such formulation as described below is to be considered solely for the purpose of illustrating the practice of the invention and in no matter is to be considered as a limitation to the scope of the invention as described in the claims appended hereto.

The successful formulation was as follows:

10 parts epoxy resin of the bisphenol A-epichlorohydrin type
6 parts hexahydrophthallic anhydride
1 part tridimethyl amino methyl phenol (DMP30)

The core laminations were assembled into stacks to form the core parts and subsequently assembled to form the core construction after the coating step. The composition was brushed at the edges thereof. The clamp rings were placed on opposite ends of the core assembly. The core assembly with the brushed-on coating was exposed to 135° centigrade for 50 minutes in an oven. When the core assembly was removed from the oven, the resinous composition was found to be cured and had become a rigid mass. The clamping rings were then removed and the assembly was held intact by the polymerized resinous composition. On subsequent testing and operation the finished transformer core was found to be operative with less production of noise. The core was subsequently taken apart and the residual evidence showed that the resin had entered the space between the tightly held juxtaposed laminations and had firmly bonded same together.

Obviously variations in the methods and structures can be made without departing from the spirit or scope of the invention.

What it is desired to secure by Letters Patent of the United States is:

1. In a method of manufacturing cores for mounting electromagnetic coils thereon to form electromagnetic devices wherein said cores include outer winding legs and a center winding leg, each formed of a stack of a predetermined number of individual lamination parts of size and configuration to form said legs and in which the method includes the steps of assembling the individual parts into stacks to form the outer winding legs and a central winding leg and assembling said so-formed winding legs with the electromagnetic coils mounted thereon to form said core construction by placing end portions of said outer winding legs abutting adjacent end portions of said central winding leg; the invention comprising the steps of applying an exterior coating of a polymerizable resinous composition at a first viscosity stage of low flowability to the abutting portions of said winding legs prior to their assembly to form said core construction, placing disposable binder means over the ends of said assembled winding legs and spaced from said ends, and thereafter, with the disposable binder means so placed, curing said resinous composition to an intermediate viscosity stage of high flowability to introduce, as by capillary action, between juxtaposed individual lamination parts and thereafter completing the cure of said resinous composition to a cured viscosity stage of zero flowability whereby said laminations are permanently bonded.

2. The method as claimed in claim 1 in which said disposable binder means are removed subsequent to the completion of curing of the resinous composition.

3. The method as claimed in claim 1 in which the composition is chosen from the group comprising epoxy resins and same is cured by heating.

4. The method as claimed in claim 1 in which said composition is chosen from the group comprising epoxy resins and includes an acid anhydride activator.

5. The method as claimed in claim 1 in which said composition is chosen from the group comprising epoxy resins and includes an acid anhydride activator and an accelerator.

6. The method as claimed in claim 1 in which said composition is applied by means of dipping said winding legs partially into said composition.

7. The method as claimed in claim 1 in which said composition is applied by means of brushing the coating along the said abutting portions of said winding legs.

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CHARLIE T. MOON, *Primary Examiner.*

R. W. CHURCH, *Assistant Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,341,939 September 19, 1967

Albert E. Feinberg et al.

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 7, for "18" read -- 19 --; column 5, line 38, for "resin" read -- resins --; line 39, for "are" read -- or --; column 6, line 19, for "ceertain" read -- certain --; line 55, for "1" read -- .1 --.

Signed and sealed this 15th day of October 1968.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents