Jan. 10, 1967 H. T. JONES 3,297,970

ELECTRICAL COIL AND METHOD OF MANUFACTURING

Filed April 7, 1965

Fig. 1.

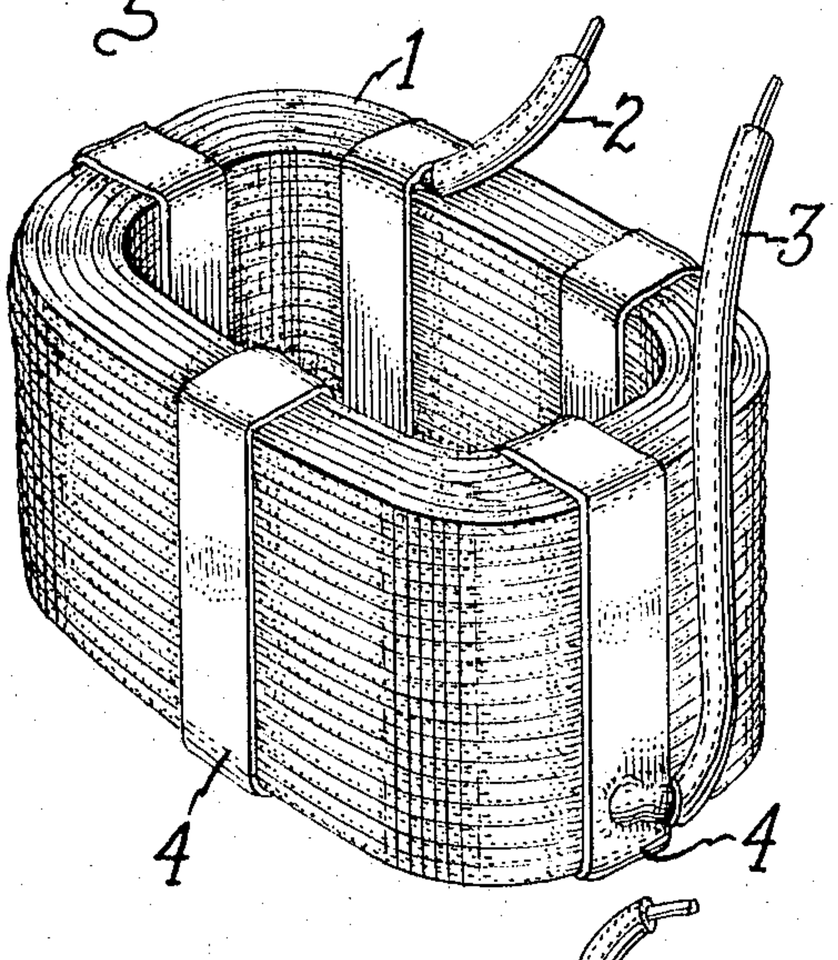


Fig. 2.

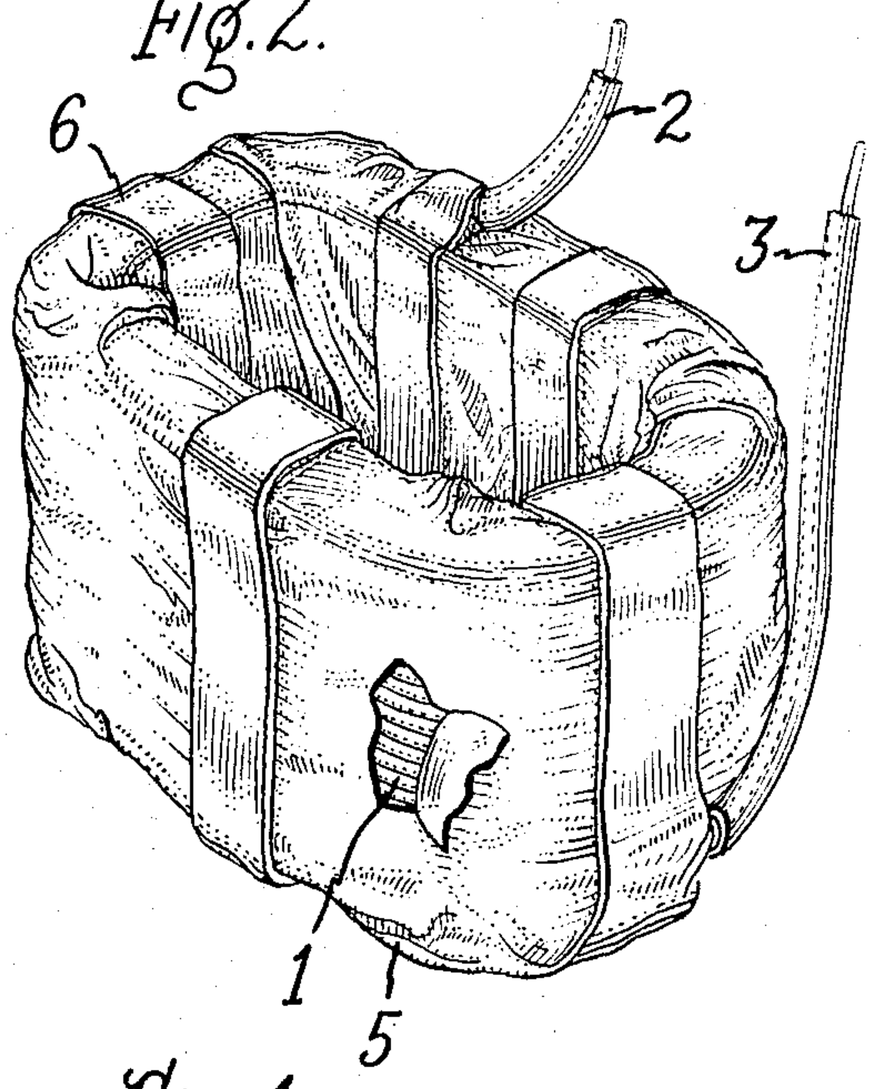


Fig. 3.

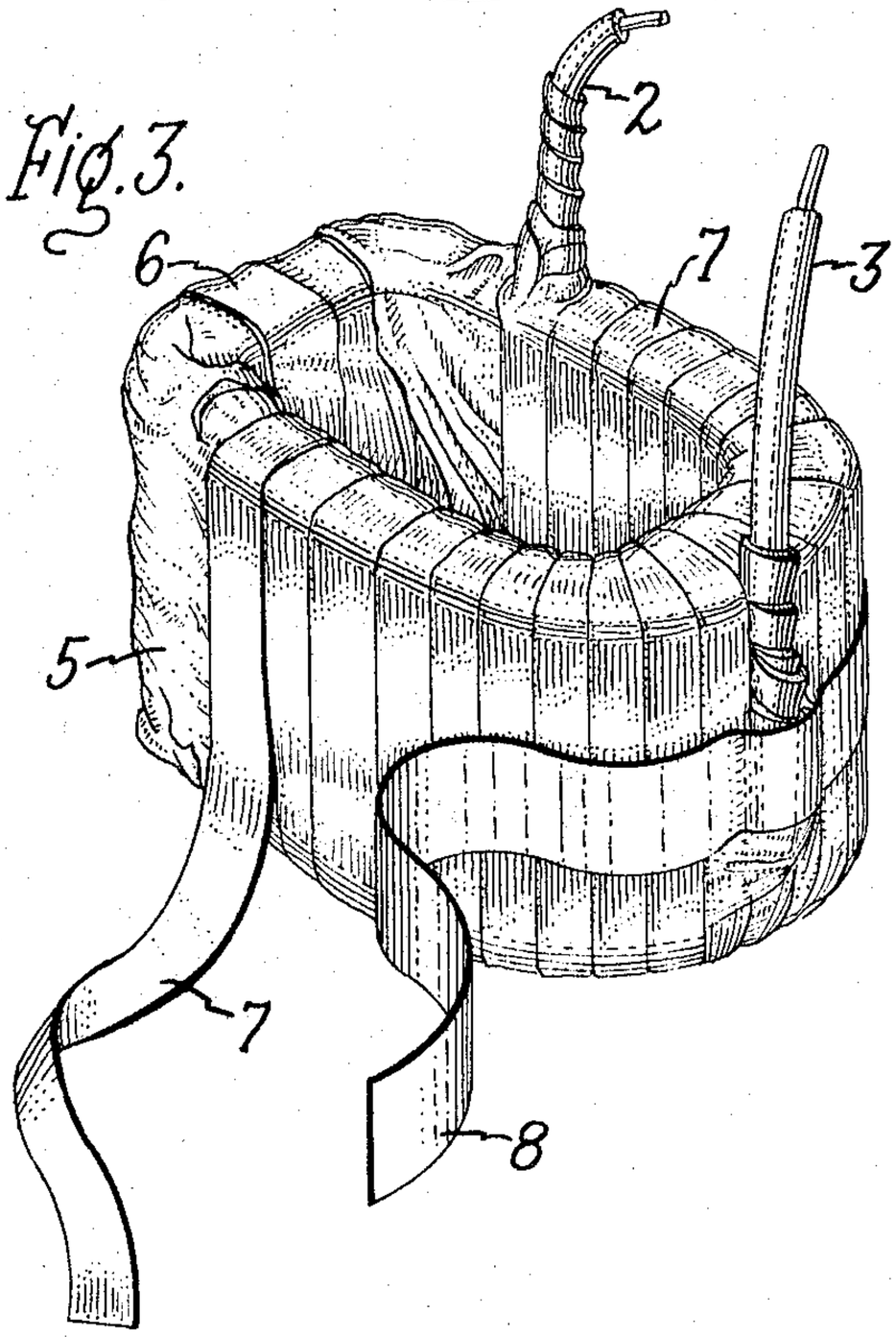
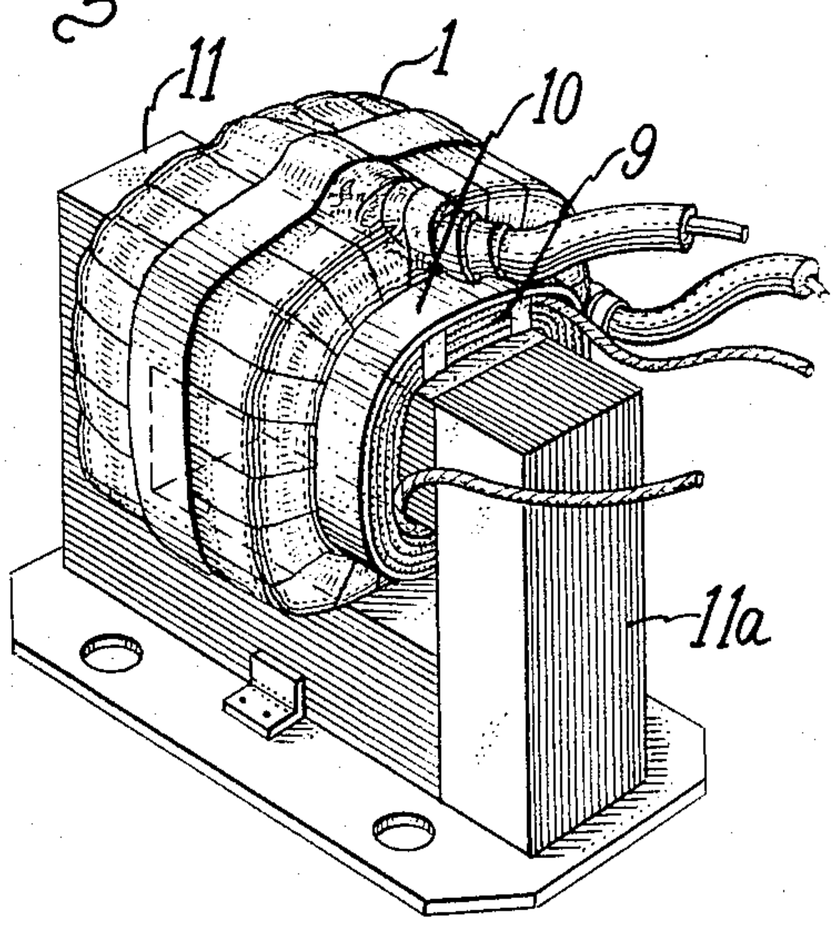


Fig. 4.



Inventor,
Howard T. Jones,
by Sidney Greenberg
His Attorney.

United States Patent Office

3,297,970

Patented Jan. 10, 1967

3,297,970
ELECTRICAL COIL AND METHOD OF MANUFACTURING

Howard T. Jones, Flat Rock, N.C., assignor to General Electric Company, a corporation of New York

Filed Apr. 7, 1965, Ser. No. 446,269
4 Claims. (Cl. 336—205)

The present invention relates to electrical coils, and more particularly concerns insulated electrical coils subject to relatively high voltage conditions and to a method of making such coils.

The invention is applicable, for example, to electromagnetic coils employed in series-connected lamp ballast transformers wherein the primary coil may be subjected to as much as 10,500 volts. In general, the invention will be found useful for insulating electrical devices which must withstand operating voltages in the range of about 600 to about 20,000 volts.

It is an object of the invention to provide electrical devices such as electrical coils, and particularly electromagnetic coils for use in ballast transformers, having improved insulation to withstand high voltage conditions.

It is another object of the invention to provide a method of making electrical devices, and especially electrical coils of the above type, and particularly a method of insulating such coils which is relatively simple and inexpensive, which lends itself for use in large scale production procedures, and provides insulated coils having excellent electrical properties and relatively smaller size than similar coils made by previously employed insulating methods.

Other objects and advantages will become apparent from the following description and the appended claims.

With the above objects in view, the present invention in one of its aspects comprises an insulated electrical device comprising, in combination, a wound coil of an elongated conductor having an insulating resin coating thereon, the coil being coated with an insulating varnish which permeates the interstices of the coil winding, a first insulating sheet material comprising a polyester resin cured in situ by heat and pressure wrapped around the coil winding, and a second insulating sheet material comprising a shrinkable polymer material wrapped around the coil and overlying the first insulating sheet material, the second insulating sheet material being heat-shrunk in situ and thereby compressing the first insulating sheet material to provide a fluid tight, dense insulating covering for the coil.

The invention will be better understood from the following description, taken in conjunction with the accompanying drawing, in which:

FIGURE 1 is view of a transformer primary coil winding to which the invention is applicable;

FIGURE 2 is a view of the FIG. 1 coil provided with an initial insulating wrapping in accordance with the invention;

FIGURE 3 is a view of the FIG. 2 coil showing a second insulating wrapping overlying the initial wrapping; and

FIGURE 4 is a view of an assembled transformer unit including the primary coil insulated in accordance with the present invention.

Referring now to the drawing, and particularly to FIG. 1, there is shown an electrical coil **1** adapted for use as the primary winding of a series ballast transformer and formed of a helically wound coil of wire and having projecting leads **2** and **3** at opposite ends of the winding covered with suitable insulating sleeves. The wire is typically composed of a copper strand coated with a suitable insulating material such as polyvinyl formal or, preferably, the polyester material disclosed in Precopio et al. Patent 2,936,296 and sold under the trademark

Alkanex. The coil is precision wound in a plurality of layers by known methods and winding apparatus, and is formed with a central opening therethrough for receiving the secondary coil winding and for inserting this assembly on the transformer core as hereinafter described.

In accordance with the process of the invention, coil **1** having its turns bound in place by spaced adhesive strips **4**, such as polyester tape or other suitable taping material, tightly encircling the winding layers and adhesively attached thereto, is dipped in an insulating varnish bath for impregnating the coil with the varnish. A particular varnish material which has been found satisfactory is the thermosetting polyester resin which is disclosed in the Precopio et al. patent mentioned above and which comprises the product of reaction of (1) a lower dialkyl ester of terephthalic or isophthalic acid, e.g., dimethyl terephthalate, (2) ethylene glycol, and (3) a saturated aliphatic polyhydric alcohol having at least three hydroxyl groups, e.g., glycerin. For brevity, this polyester resin will herein be referred to as Alkanex.

Other known or suitable insulating varnishes, however, may alternatively be used, such as oleo-resinous varnishes, oil-modified phenolics, styrene-modified polyester varnishes, and alkyd resins. The Alkanex varnish described is preferred, however, for its thermal stability coupled with excellent mechanical, chemical and electrical properties.

In a usual procedure, coil **1** is preheated to above 190° C. before the varnish treatment, and it is then dipped into an Alkanex bath at room temperature for 5 minutes, or for a sufficient period to enable the liquid varnish to permeate into the interstices of the coil turns. The coil is then removed from the bath, and the excess varnish allowed to drain off. The thus treated coil is then heated in an oven at about 125° C. for about 3 hours to cure the varnish, after which the coil is force cooled to room temperature.

After being cooled, the coil is preferably provided with a layer of pressure-sensitive adhesive coated polyester tape (e.g., Mylar) applied to opposite edge faces of the coil, so as to insure adequate insulation, especially at the corners, to withstand the high electrical stress to which the coil is subjected during subsequent electrical testing.

The coil is then wrapped with a sheet of insulating material composed preferably of glass cloth impregnated with a B stage (i.e., semi-cured) polyester resin, the coil being shown in FIG. 2 wrapped with such polyester resin impregnated sheet **5**. As shown, the polyester resin sheet is folded into the central opening of the coil so as to conform as closely as possible to the coil form, and is there held in place by spaced adhesive tapes **6**.

The polyester resin which impregnates sheet **5** is preferably a completely polymerizable resin composed of a copolymer of an unsaturated alkyd resin and a vinyl monomer. Such copolymers and the sheet material incorporating the same which may be employed in practicing the present invention are disclosed in the patent to Loritsch 2,528,235, and the disclosure of the latter patent is accordingly incorporated herein by reference.

As there disclosed, the polyster resin composition may be formed from a mixture which includes (1) a polymerizable unsaturated alkyd resin obtained by the esterification reaction of a mixture of ingredients comprising a polyhydric alcohol and a polycarboxylic acid, (2) a polyallyl ester, and (3) a catalyst for accelerating the copolymerization of the ingredients of (1) and (2). Unsaturated alkyd resins which may be used are, for example, diethylene glycol maleate, diethylene glycol maleate phthalate, glyceryl itaconate, glyceryl maleate, ethylene glycol maleate, diethylene glycol itaconate, propylene glycol fumarate, triethylene glycol maleate, esterification products of ethylene glycol, itaconic and acid and phthalic

anhydride, of diethylene glycol, itaconic acid and succinic acid, of ethylene glycol, maleic anhydride and adipic acid, of diethylene glycol, maleic anhydride and itaconic acid, of diethylene glycol, maleic anhydride and stearic acid, of glycerine, maleic anhydride and phthalic anhydride, of glycerine, maleic anhydride and octyl alcohol, etc. Other examples of polymerizable unsaturated alkyd resins that may be used are given, for example, on page 4 of D'Alelio Patent No. 2,308,495, issued January 19, 1943.

As the polyallyl ester ingredient there may be used, for example, diallyl phthalate, the diallyl esters of carbonic, oxalic, malonic, succinic, glutaric, adipic, pimelic, suberic, sebacic, azelaic, maleic, fumaric, itaconic, benzoyl phthalic, mesaconic, citraconic, tartronic, malic, gluconic, tartaric, isophthalic, terephthalic, benzophenone-2,4'-dicarboxylic, etc., acids; di- and tri-allyl citrates, tricarballylates, aconitates, phosphates, silicates, etc.; tetra-allyl silicate, the tetra-allyl ester of benzene tetracarboxylic acid, etc.

The foregoing resin mixture preferably includes a catalyst such as benzoyl peroxide, or other organic and inorganic peroxides as disclosed in the Loritsch patent, as well as the other catalysts disclosed by Loritsch.

While the inclusion of a polyvinyl acetal resin such as polyvinyl formal may provide optimum results, as taught by Loritsch, such a component is not absolutely necessary in the polyester resin wrapping sheet employed in accordance with the invention.

In a particular B stage polyester resin sheet material found suitable for purposes of the invention, the sheet material is composed of glass cloth impregnated with a polyester resin comprising a mixture of equal parts of diallyl phthalate and diethylene glycol maleate and a small amount of a polymerization catalyst, e.g., benzoyl peroxide.

The polyester resin impregnated sheet is such that prior to use, the resin preferably is in dry, uncured, or semi-cured, slightly tacky condition and the sheet is flexible and conformable to the surface to which it is applied, only heat and pressure being required to cure the resin and harden the sheet into a tought, dense bonded structure. While glass fiber cloth is preferred for the base material of the sheet, other base sheet material may be employed, such as asbestos material, nylon cloth, or other equivalent material suitable for use as a wrapping sheet. It will be understood that if desired the wrapping sheet may be in the form of tape and wound around the coil as described in connection with wrapping tape **7** below.

While the above described polyester resin sheet material is particularly suitable for purposes of the invention, wrapping sheet having other insulating resin material incorporated therein, such as epoxy resins of known type, may be used, such resins being condensation products of polyhydroxy compounds (such as polyhydric phenols and polyhydric alcohols) and epichlorhydrin. Such epoxy resins impregnated in the sheet may be liquid epoxides in the B stage, or uncured solid epoxides deposited in solvent solution on the base tape.

Following the wrapping of the coil with the polyester sheet (or equivalent sheet) the coil **1** may be wrapped around its outside surface, if necessary or desirable to provide added insulation, with a sheet of micamat, i.e., a sheet of reconstituted mica paper, but this step is optional so far as the present invention is concerned.

The coil is then tightly wrapped, as shown in FIG. 3, with a strip of irradiated polyethylene tape **7** to provide spirally wound overlapping turns of this tape completely covering the underlying polyester sheet wrapping **5**, the end of tape **7** after complete wrapping being inserted under the final turn. A strip of adhesive Mylar tape **8** is then wound around the outer circumference of the coil to hold the wrapping turns in place.

The irradiated polyethylene tape **7** has the characteristic

of shrinking when heated. The method of making such shrinkable polymer tape is disclosed, for example, in the patent to Mathes et al. 2,929,744, and the disclosure of the latter patent is accordingly incorporated by reference herein. In accordance with the invention, the coil wrapped with irradiated polyethylene tape **7** is heated to a temperature of about 190° C. which results in shrinking the tape, thus applying pressure to the underlying polyester resin wrapping sheet so that the latter, under the heat and pressure applied, cures to a hard, strong, dense, fluid-tight, highly insulating covering for the wound coil.

Such heating of the irradiated polyethylene tape to shrink the same is advantageously carried out, in accordance with another aspect of the invention, after the fully wrapped primary coil is assembled with a secondary coil and a transformer core. In such procedure, the secondary or low voltage coil, which typically is somewhat longer than the primary coil to provide extra electrical creep distance in the transformer assembly and which is not provided with a wapping as on the primary coil, is nested within the wrapped primary coil with a sheet of micamat arranged between the two coils. The two coils are then assembled on a transformer core. As shown in FIG. 4, such assembly comprises the wrapped primary coil **1** and nested secondary coil **9** with a sheet of micamat **10** arranged therebetween inserted over a leg of transformer core **11** with the yoke **11***a* closing the open end of the transformer core.

This transformer assembly is then preheated to about 190° C. and dipped in an insulating varnish bath such as Alkanex, as previously described in connection with the varnish impregnation of the unwrapped primary coil. After removal of the assembly from the varnish bath, the excess varnish is allowed to drain, and the assembly is cured in an oven for 3 hours at about 125° C. to cure the varnish, after which the assembly is cooled.

Such treatment provides a number of desirable results. It cures to hardness the B stage polyester resin sheet material constituting the underwrap on the primary coil; it shrinks the irradiated polyethylene tape, providing pressure on the underlying polyester sheet wrapping for improved cure of the latter and promoting its optimum insulating properties, it impregnates the secondary coil with an insulating varnish and thereby eliminates the air voids therein; it impregnates the transformer core with the insulating varnish; and it bonds all components of the transformer assembly together in a unitary, mechanically stable, thermally and chemically resistant, well-insulated structure.

While particularly satisfactory results have been obtained with the use of irradiated polyethylene tape as the shrinkable wrapping material, other types of shrinkable polymer tape or wrapping material may be used, such as post-oriented polyethylene terephthalate for the purpose of applying a contracting force on the under layer of polyester resin sheet material, such post-oriented polyethylene terephthalate being disclosed in detail in the patent to Marshall 2,993,820.

It will be understood that while the present invention has been described mainly with respect to the primary winding of a ballast transformer, the process of the invention is applicable to various types and forms of electrical devices which may be advantageously insulated by the disclosed multiwrap insulating procedure of the present invention to improve their resistance to high voltage conditions.

While the present invention has been described with reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the scope of the invention. Therefore, the appended claims are intended to cover all such equivalent variations as come within the true spirit and scope of the invention.

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

1. An insulated electrical device comprising, in combination, a wound coil of an elongated conductor having an insulating resin coating thereon, said coil being coated with an insulating varnish which permeates the interstices of the coil winding, a first insulating sheet material comprising a porous inorganic sheet impregnated with a thermosetting resin cured by heat and pressure and wrapped around the coil winding, and a second insulating sheet material comprising a shrinkable polymer material wrapped around said coil and overlying said first insulating sheet material, said second insulating sheet material being heat shrunk in situ and thereby compressing said first insulating sheet material to provide a fluid tight, dense insulating covering for said coil, the thus wrapped coil having a coating thereon of heat-cured insulating varnish.

2. An insulated electromagnetic device comprising, in combination, an electromagnetic core member, a low voltage secondary coil surrounding said core member, and a high voltage primary coil surrounding said secondary coil, said primary coil being formed of a wound elongated conductor having an insulating resin coating thereon, said primary coil being coated with an insulating varnish which permeates the interstices of the coil winding, a first insulating sheet material comprising a porous inorganic sheet impregnated with a polyester resin cured by heat and pressure and wrapped around said primary coil winding, a second insulating sheet material comprising a shrinkable polymer material wrapped around said coil and overlying said first insulating sheet material, said second insulating sheet material being heat-shrunk in situ and thereby compressing said first insulating sheet material to provide a fluid tight, dense insulating covering for said primary coil, the assembly of said core member and coils having a coating thereon of a heat-cured insulating varnish material.

3. An insulated electromagnetic device comprising, in combination, an electromagnetic core member, a low voltage secondary coil surrounding said core member, and a high voltage primary coil surrounding said secondary coil, said primary coil being formed of a wound elongated conductor having an insulating resin coating thereon, said

primary coil being coated with an insulating varnish which permeates the interstices of the coil winding, a first insulating sheet material comprising a porous inorganic sheet impregnated with a polyester resin cured by heat and pressure and wrapped around said primary coil winding, a second insulating sheet material comprising a heat shrinkable polymer material composed of irradiated polyethylene wrapped around said primary coil and overlying said first insulating sheet material, said second insulating sheet material being heat-shrunk in situ and thereby compressing said first insulating sheet material to provide a fluid tight, dense insulating covering for said primary coil, the assembly of said core member and coils having a coating thereon of a heat-cured insulating varnish material.

4. The method of making a transformer which comprises forming a first wound coil of an elongated conductor having an insulating coating thereon, applying an insulating varnish to said coil to bond the winding turns together and fill the voids therebetween, wrapping a first insulating sheet material comprising a porous inorganic sheet impregnated with a semi-cured heat and pressure hardenable polyester resin around the thus treated coil, wrapping a second insulating sheet material comprising a heat shrinkable polymer material composed of irradiated polyethylene around said coil overlying said first insulating sheet material, inserting a second coil within said wrapped insulated coil, assembling said coils on a transformer core member, heating said assembly of coils and core for shrinking said second insulating sheet material, whereby said first insulating sheet material is cured by the heat and pressure thus applied to provide a fluid-tight, dense insulating covering for said first coil, and applying an insulating varnish to said assembly of core and coils.

References Cited by the Examiner

UNITED STATES PATENTS

2,929,744	3/1960	Mathes et al.	117—138.8 X
2,993,820	7/1961	Marshall	156—86
3,048,651	8/1962	Howard et al.	174—120

LARAMIE E. ASKIN, *Primary Examiner.*

C. A. TORRES, T. J. KOZMA, *Assistant Examiners.*