

Jan. 8, 1963

M. G. LEONARD ETAL
PROGRESSIVE WINDING OF COILS

3,071,845

Filed April 24, 1957

Fig. 1.

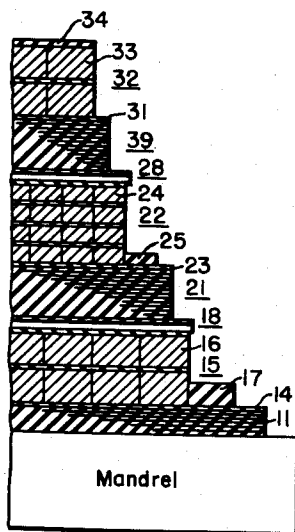
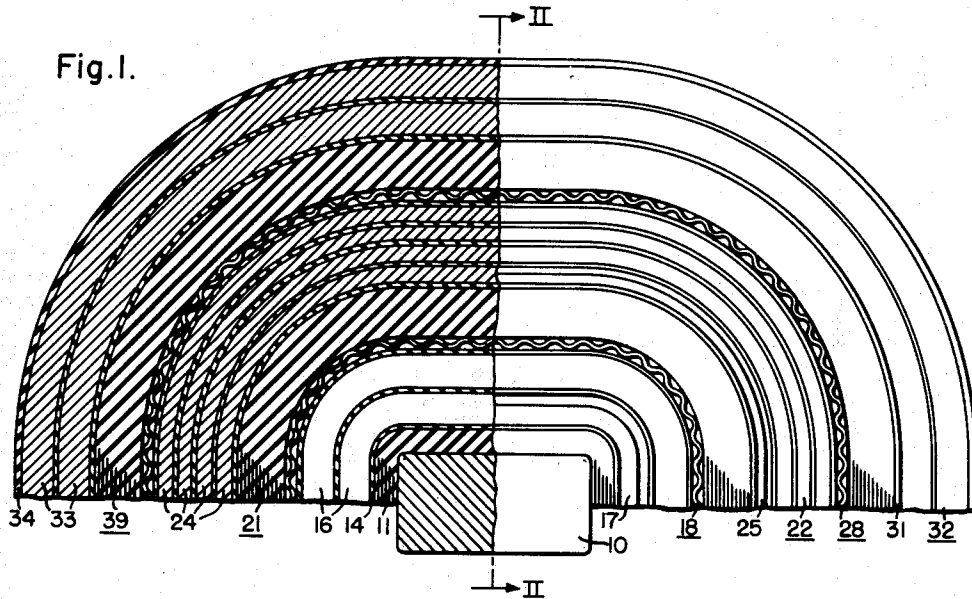


Fig. 2.

Fig. 3.

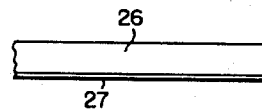


Fig. 4.

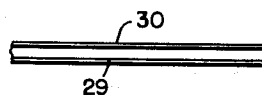


Fig. 5.

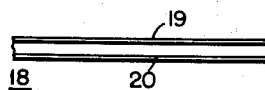
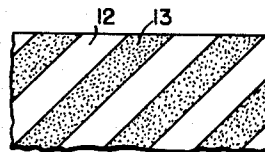


Fig. 6.



WITNESSES

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3,071,845

PROGRESSIVE WINDING OF COILS

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7 Claims. (Cl. 29—155.57)

The invention relates generally to coil structures and the method of making them, and more particularly to the preplacing of adhesives and bonding materials in the winding of the coil.

In the manufacture of coil structures for transformers and other inductive apparatus, it has long been the practice to manufacture the low voltage windings and high voltage windings separately and then interfit them to get the units in their proper relative positions. The interfitting of the windings and other parts presents an expensive operation and often results in damage to the parts.

The object of the invention is to provide a method of manufacturing coils in which the adhesives and bonding materials are introduced during the manufacturing operation to render unnecessary the dipping of the coils in varnish or other bonding materials.

Another object of the invention is to provide for so winding the primary and secondary coils of an inductive device relative to one another that a rugged coil structure results which is capable of withstanding the severest operating and test conditions up to short circuit loads.

It is also an object of the invention to provide a method of manufacturing coils in which all the member are built on one another with the adhesives and bonding materials preplaced to avoid the interfitting of parts that have been manufactured separately.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the several steps and the relation and order of one or more of such steps with respect to each of the others, and the article possessing the features, properties, and the relation of elements, which are exemplified in the following detailed description and the scope of application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawing, in which:

FIGURE 1 is a view partly in end elevation and partly in section showing details of the structure;

FIG. 2 is a view in section taken along the line II—II of FIG. 1;

FIG. 3 is a view in side elevation of a portion of a strip employed for holding the turns of the winding in place;

FIG. 4 is a view in side elevation of a portion of a sheet for permitting the flow of a liquid dielectric into the windings showing details of its structure;

FIG. 5 is a view in side elevation of a portion of a bonding sheet showing details of its structure; and

FIG. 6 is a view in top elevation of a portion of the sheet illustrated in FIG. 5.

The structure illustrated is manufactured with all the elements required preplaced. Therefore, when the winding or coil is completed and processed there is no interfitting of parts necessary.

Referring now to the structure illustrated in FIG. 1, the method employed involves first selecting a mandrel 10 of the required shape and size. This mandrel will be made from some suitable material such as iron and will have the dimensions that are required to provide a window

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in the final structure that will be of predetermined size depending on the specifications to be met.

In starting the winding one or more turns of paper is applied to the mandrel 10. This paper may be of any ordinary type commonly used in the building of coils and is applied to the mandrel to facilitate the removal of the coil without damage to the essential members of the structure.

A tube or tubular member or coil form 11 is then wound on top of the turn of paper applied to the mandrel. The number of turns of paper or other fibrous material utilized in making the tubular member 11 will depend on the specification of the transformer. In making small transformers, for instance up to ten kva., it is found that about six turns of a paper of .015 inch in thickness is sufficient to give the required insulation for the low voltage winding.

In building this tubular member 11 according to the present method, it is necessary to provide for the penetration of oil or other liquid dielectric through the paper and for the proper bonding of the turns of paper required to make the tubular member. Therefore, the paper employed is provided with a discontinuous coating of some suitable material such as an epoxy resin which when treated will thoroughly bond the turns of paper to one another.

The paper shown in FIG. 6 comprises a sheet 12 which may be made to meet any of the well known specifications utilized in building coils or windings for transformers or other inductive apparatus. Applied to this paper is an epoxy resin 13. This resin may be applied in strips as illustrated or in any other suitable manner known in the art provided it is discontinuous and leaves sufficient areas uncoated to permit the penetration of a liquid dielectric to penetrate the uncoated portions of the paper. The epoxy resin is shown applied in strips because this is one of the well known methods of applying a predetermined amount of the bonding material and also to assure a sufficient uncoated area to provide for the penetration of the liquid dielectric.

When a tubular member of adequate thickness has been built up, at least one outside turn 14 which has been specially treated will be applied. In the preferred embodiment the outside turn should have an epoxy resin on both sides. It is desirable to utilize an epoxy or similar resin which is neither tacky nor sticky at room temperature and thereby facilitates use but which when subjected to predetermined temperatures passes through a tacky condition before reaching a thermosetting condition, thereby binding the conductors to the paper and successive layers of conductors and paper to one another. Good results have been found in using a heat sensitive adhesive such as an epon resin dissolved in a suitable solvent. Many resins of this kind are known in the art and may be employed. The epoxy resin will be so applied that when the turn is completed it will present a coated surface. The low voltage winding or coil shown generally at 15 is wound on top of the resin carried by the outer turn 14 of the tubular member 11. The conductor employed in the winding 15 may be of any size and carry the insulation ordinarily employed in such windings. It is common to use a cotton covered conductor and wind it in layers as shown in FIG. 2. The number of turns of the conductor 16 will depend on the specification to be met. In this embodiment of the invention we have illustrated two layers of turns in the low voltage coil shown generally at 15.

In order to support the turns of the low voltage winding 15 against lateral movement, a strip of material 17 such as a well known pressboard is applied. The strip 17 may be of any suitable height and width. As shown, a strip which is about $\frac{2}{3}$ the height of the conductor is

utilized. In preparing this strip an adhesive such as an epon resin dissolved in any of its well known solvents will be applied to one side and one turn will be wound on the tubular member 11 near the end. The adhesive will bond the strip to the turn 14 of the tubular member. When a strip is applied in this manner it need not be made of any special shape. In this case it is a strip of pressboard substantially rectangular in cross section.

A spacer shown generally at 18 is then wound over the low voltage winding shown generally at 15. This spacer is preferably a corrugated fibrous sheet coated on both sides with an epon resin or some suitable resinous material as shown in FIG. 5. The layers of shellac 19 and 20 may be discontinuous as shown in FIG. 6.

It is not always necessary to use a corrugated paper. An ordinary paper with rectangular spacers of wood or some other nonmetallic material may be employed depending on the specifications to be met. The purpose of using a corrugated or other paper is to provide ducts to facilitate the entry of a dielectric liquid adjacent to the winding 15.

The next step involves the winding of a tubular member shown generally at 21 on the corrugated sheet shown generally at 18. This tubular member 21 will be made much thicker than the tubular member 11. It will also be made from paper having discontinuous coatings of an epoxy resin applied to both sides as shown in FIG. 6. The number of turns of paper in the tubular member shown generally at 21 will depend on the insulating values to be obtained. The tubular member 21 will have to withstand the voltage gradient between the high voltage coil shown generally at 22 and the low voltage coil 15. In finishing the tubular member 21 a turn or turns having an epoxy resin on both sides will be employed. The temperature sensitive epoxy resin will be exposed to receive the turns of the conductor.

The high voltage coil or winding shown generally at 22 will be wound on the tubular member 21. Generally in winding the high voltage coil 22 the conductor 24 is smaller in cross section than the conductor 16 and the coil 22 has many more turns than the low voltage coil 15. The size of the conductor and the number of turns will depend on the specification to be met and may be determined by anyone skilled in the art. A holding strip shown generally at 25 similar to the strip 17 is applied to the tubular member 21 at the end of the turns of the high voltage winding. As shown in FIG. 3, the strips 17 and 25 are the well known fibrous material generally known as pressboard 26 having a coating of an epoxy resin 27 applied for bonding it to the tubular members.

It will be noted that in building up the high voltage coil shown generally at 22 that between the turns of the coil, layers of paper are applied. These layers of paper will have an epoxy resin on both sides. This will prevent the turns of the winding from moving relative to one another.

Next the turn of a corrugated or wavy fibrous material similar to the one shown generally at 18 is applied. This turn of corrugated fibrous material will be designated generally as 28. It comprises a paper or other fibrous material such as shown in FIG. 4 having a coating of an epoxy resin 29 on one side and an equivalent material 30 on the other side. This corrugated or wavy layer 28 will permit the penetration of a liquid dielectric adjacent to the winding 22. On top of the corrugated layer 28 another tubular member shown generally at 39 corresponding to the tubular member 21 is wound. It should be about the same thickness as the tubular member 21 since it will have to withstand the same voltage. The outer turn 31 of the tubular member 39 will have an epoxy resin applied on the side facing outwardly.

The next part is the low voltage winding shown generally at 32. It will be the same as the low voltage winding 15. This winding will be made from some insulated conductor 33 commonly used in building low voltage

windings. As stated in connection with low voltage coil 15, the number of turns employed will depend on the specification of the transformer or other inductive apparatus.

It has been found to be good practice to wind the completed structure with a number of turns of some suitable tape to hold the members in substantially the as wound position. A cotton tape such as shown at 34 has been found to be satisfactory.

In making windings of this kind, it is generally desirable to put layers of paper having an epoxy resin on both sides between the layers of conductors in the high voltage coils as described hereinbefore. Sometimes it will be desirable to place similar layers of paper having an epoxy resin on both sides between the layers of the low voltage windings.

After the winding has been made, it will be subjected to a heat treatment at a temperature of about 130° C. to completely dry it. The length of time to which the windings or coils are subjected to this temperature will depend on the conditions to be met. Anyone skilled in this art can readily determine how much heating is required.

After the coil has been properly dried it will be placed in a vacuum tank and subjected to a vacuum of the order of about 1 centimeter of mercury. Vacuum tanks suitable for this purpose are well known in the art and so have not been illustrated.

The evacuation process removes all gases, principally air, from the winding. The removal of air is important since if the paper employed retains small bubbles of air, in the process of testing or even in use, there may be a breakdown of the insulation at points where the air bubbles have been retained.

After the evacuation process has been completed, a dielectric liquid such for example as oil is flowed into the tank and the whole winding thoroughly impregnated. Thus we have a process in which all the bonding materials and adhesives are so preplaced that when the winding is finished and processed the structure comprising the conductors, insulation and wound coils will be firmly united and the well known varnish dip and other processing will be unnecessary.

Since certain changes in carrying out the above process and certain modifications in the article which embodies the invention may be made without departing from its scope, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

We claim as our invention:

1. In the method of providing a unitary coil assembly having high-voltage windings and low-voltage windings, said assembly being adapted to operate immersed in a liquid dielectric, the steps of: (1) winding a strip of paper having a discontinuous coating of thermosetting resin thereon to provide a coil form, said resin coating being discontinuous in the lengthwise direction of said strip or paper the uncoated portion of said paper being penetrable by liquid dielectric (2) winding low-voltage windings on said coil form, (3) providing spacer means to provide ducts adjacent said low-voltage winding, said duct means permitting the entry of the liquid dielectric adjacent said low-voltage windings, (4) winding paper having a discontinuous coating of thermosetting resin thereon on said duct means to form a tube, said tube being of such thickness as to effectively insulate against voltage breakdown between the high-voltage and low-voltage windings due to the potential gradient between the high-voltage and the low-voltage windings, said resin coating being discontinuous in the lengthwise direction of said paper, (5) winding high-voltage windings on said tube, and (6) curing said resin to cause said resin to thermoset and firmly unite said coil assembly into a rigid structure, said resin being non-tacky at winding temperature, but during curing passes through a tacky stage and thermosets.

2. In the method of providing a unitary coil assembly

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having high-voltage windings and low-voltage windings, said assembly being adapted to operate immersed in a liquid dielectric, the steps of: (1) winding a strip of paper having a discontinuous coating of thermosetting resin thereon to provide a coil form, the uncoated portion of said paper being penetrable by a liquid dielectric the resin coating being discontinuous in the lengthwise direction of said paper, (2) winding low-voltage windings on said coil form, (3) winding a corrugated fibrous sheet having a coating of thermosetting resin thereon on said low-voltage windings, said corrugated sheet providing ducts to permit the entry of the liquid dielectric adjacent said low-voltage windings, (4) winding a sheet of paper having a discontinuous coating of thermosetting resin thereon on the corrugated fibrous sheet to form a tube, the resin coating being discontinuous in the lengthwise direction of said paper, said tube being of such thickness as to effectively insulate against voltage breakdown between the high-voltage and the low-voltage windings due to the potential gradient between the high-voltage and low-voltage windings, (5) winding high voltage windings on said tube, and (6) curing said resin to cause said resin to thermoset and firmly unite said coil assembly into a rigid structure, said resin being non-tacky at winding temperature, but during curing passes through a tacky stage and thermosets.

3. In the method of providing a unitary coil assembly having high-voltage windings and low-voltage windings, said assembly being adapted to operate immersed in a liquid dielectric, the steps of: (1) winding a strip of paper having a discontinuous coating of thermosetting resin thereon to provide a form, the resin coating being discontinuous in the lengthwise direction of said strip of paper, the uncoated portions of said paper being penetrable by liquid dielectric, (2) winding low-voltage windings on said form, (3) winding a corrugated fibrous sheet having a coating of thermosetting resin thereon on said low-voltage winding, said corrugated sheet providing ducts to permit the entry of the liquid dielectric adjacent said low-voltage windings, (4) winding a sheet of paper having a discontinuous coating of thermosetting resin thereon on the corrugated fibrous sheet to form a tube, the coating of resin being discontinuous in the lengthwise direction of said sheet of paper, said tube being of such thickness as to effectively insulate against breakdown between the high-voltage and low-voltage windings due to the potential gradient between the high-voltage and the low-voltage windings, (5) winding high-voltage windings on said tube, (6) winding a second corrugated sheet having a coating of thermosetting resin thereon on said high-voltage winding, said second corrugated sheet providing ducts to permit the entry of the liquid dielectric adjacent to said high-voltage windings, (7) winding a sheet of paper having a discontinuous coating of thermosetting resin thereon on said second corrugated fibrous sheet to form a second tube, the coating of resin being discontinuous in the lengthwise direction of said sheet of paper, said second tube being of such thickness as to effectively insulate against voltage breakdown between the high-voltage and the low-voltage windings because of the potential gradient between the windings, (8) winding a second low-voltage winding on said second tube, and (9) curing said resin to cause said resin to thermoset and firmly unite said coil assembly into a rigid structure, said resin being non-tacky at winding temperature, but during curing passes through a tacky stage and thermosets.

4. In the method of providing a coil assembly having high-voltage windings and low-voltage windings, said assembly being adapted to operate immersed in a liquid dielectric, the steps of: (1) winding a strip of paper having a discontinuous coating of thermosetting resin thereon to provide a form, the coating of resin being discontinuous in lengthwise direction of said strip of paper, the uncoated portion of said paper being penetrable by liquid dielectric, (2) winding a turn of paper having a coating

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of thermosetting resin on both sides on the form, (3) winding low-voltage windings on said resin coated paper, (4) winding a corrugated fibrous sheet having a coating of thermosetting resin thereon on said low-voltage windings, said corrugated sheet providing ducts to permit the entry of the liquid dielectric adjacent to said low-voltage windings, (5) winding a sheet of paper coated on both sides with a discontinuous coating of thermosetting resin on the corrugated fibrous sheet to form a tube, the coating of resin being discontinuous in the lengthwise direction of said sheet of paper, said tube being of such thickness as to effectively insulate against voltage breakdown between the high-voltage and low-voltage windings due to the potential gradient between the windings, (6) winding a high-voltage coil on said tube, and (7) curing said resin to cause said resin to thermoset and firmly unite said coil assembly into a rigid structure, said resin being non-tacky at winding temperature, but during curing passes through a tacky stage and thermosets.

5. In the method of providing a coil assembly having high-voltage windings and low-voltage windings, said assembly being adapted to operate immersed in a liquid dielectric, the steps of: (1) winding a strip of paper having a discontinuous coating of resin thereon to provide a form, the coating of resin being discontinuous in the lengthwise direction of said strip of paper, the uncoated portion of said paper being penetrable by liquid dielectric, (2) winding a turn of thermosetting paper having a coating of resin on both sides on the form, (3) winding low-voltage windings on the turn of resin coated paper, (4) winding a corrugated fibrous sheet having a coating of thermosetting resin thereon on said low-voltage windings, said corrugated sheet providing ducts to permit the entry of the liquid dielectric adjacent to said low-voltage windings, (5) winding a sheet of paper coated on both sides with a discontinuous coating of thermosetting resin on the corrugated fibrous sheet to form a tube, the coating of resin being discontinuous in the lengthwise direction of said sheet of paper, said tube being of such thickness as to effectively insulate against voltage breakdown between the high-voltage and low-voltage windings due to the potential gradient between the windings; (6) winding a high-voltage coil on said tube, (7) winding a second corrugated fibrous sheet having a coating of thermosetting resin thereon on said high-voltage winding, said corrugated sheet providing ducts to permit the entry of the liquid dielectric adjacent to said high-voltage windings, (8) winding a strip of paper having a discontinuous coating of thermosetting resin thereon on said second corrugated sheet to provide a second tube, the uncoated portions of said paper being penetrable by the liquid dielectric, the coating of resin being discontinuous in the lengthwise direction of said strip of paper, said second tube being of such thickness as to effectively insulate against voltage breakdown between the high-voltage and the low-voltage windings due to the potential gradient between the windings, (9) winding a second low-voltage winding on said second tube, and (10) curing said resin to cause said resin to thermoset and firmly unite said coil assembly into a rigid structure, said resin being non-tacky at winding temperature, but during curing passes through a tacky stage and thermosets.

6. In the method of providing a coil assembly having high-voltage windings and low-voltage windings, said assembly being adapted to operate immersed in a liquid dielectric, the steps of: (1) winding a strip of paper having a discontinuous coating of thermosetting resin thereon to provide a form, the coating of resin being discontinuous in the lengthwise direction of said strip of paper the uncoated portion of said paper being penetrable by the liquid dielectric (2) winding a strip of insulating material adjacent each end of said coil form, (3) winding low-voltage windings on said coil form between said strips of insulating material, (4) winding a corrugated fibrous sheet having a coating of thermosetting resin on

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both sides on said low-voltage winding, said corrugated sheet providing ducts to permit the entry of the liquid dielectric adjacent to said low-voltage windings, (5) winding a sheet of paper coated with a thermosetting resin on the corrugated fibrous sheet to form a tube, the coating of resin being discontinuous in the lengthwise direction of the sheet of paper, said tube being of such thickness as to effectively insulate against voltage breakdown between the high-voltage and low-voltage windings because of the potential gradient between the windings, (6) winding a strip of insulating material adjacent each end of said tube; and (7) winding high-voltage windings on said tube between said strips of insulating material, and (8) curing said resin to cause said resin to thermoset and firmly unite said coil assembly into a rigid structure, said resin being non-tacky at winding temperature, but during curing passes through a tacky stage and thermosets.

7. The method of providing a unitary coil assembly having first and second electrical windings, said assembly being adapted to operate immersed in a liquid dielectric, the steps of: (1) winding a sheet of paper to provide a coil form, said sheet of paper having strips of thermosetting resin thereon, said strips of thermosetting resin being located generally cross-wise to the length of said sheet of paper, the portions of said sheet of paper between said strips of thermosetting resin being penetrable by liquid dielectric, (2) winding first electrical windings on said coil form, (3) providing duct means adjacent said first electrical winding said duct means permitting the entry of the liquid dielectric adjacent said first windings, (4) winding a second sheet of paper on said duct means, said second sheet of paper having strips of thermo-

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setting resin thereon, said strips of thermosetting resin being located generally cross-wise to the length of said second sheet of paper, the portions of said second sheet of paper between said strips of thermosetting resin being penetrable by liquid dielectric, (5) winding second electrical windings on said second wound sheet of paper, and (6) curing said resin to cause said resin to thermoset and firmly unite said coil assembly into a rigid structure, said thermosetting resin being non-tacky at the winding temperature, but during curing passes through a tacky stage to bond all the layers of paper and windings, together and reaches a thermoset condition at which the complete coil assembly is a rigid structure.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,071,845

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Merrill G. Leonard 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 56, for "or" read -- of --; line 57, after "paper", first occurrence, insert a comma; column 5, line 6, after "dielectric" insert a comma; line 73, after "in" insert -- the --; column 6, line 28, strike out "thermosetting"; line 29, after "of" insert -- thermosetting --; line 69, after "paper" insert a comma; column 7, line 12, for "tube; and" read -- tube, --; line 29, after "winding" insert a comma; column 8, line 11, after "windings" strike out the comma.

Signed and sealed this 23rd day of July 1963.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

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