

United States Patent

Feather

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[54] **METHOD OF MAKING DISK-TYPE
WINDINGS FOR ELECTRICAL
INDUCTIVE APPARATUS**

2,632,041 3/1953 Bilodeau.....336/185 X
2,918,639 12/1959 Beymer336/185

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[21] Appl. No.: **112,657**

OTHER PUBLICATIONS

Birks, G. B., Modern Dielectric Materials, Heywood &
Co., 1960, pp. 130-133.
Modern Plastics, Oct. 1951, p. 186.

Primary Examiner—E. A. Goldberg

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[52] U.S. Cl.....**29/605, 336/187**
[51] Int. Cl.....**H01f 7/06**
[58] Field of Search.....336/60, 185, 186, 187, 207;
29/605, 593; 174/146

[57] ABSTRACT

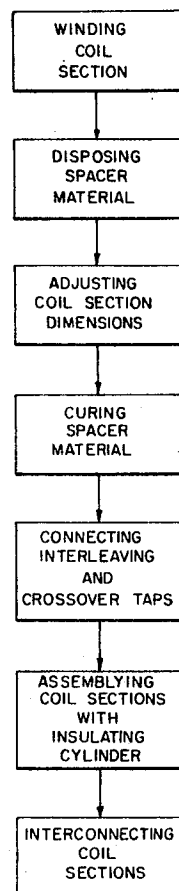
A disk-type winding for electrical inductive apparatus which is constructed from individual coil sections containing one or more disk-type coils. The individual sections are wound separately with the conductors secured by a bonding material. The bonding material also serves as a spacing member when the coil sections are assembled into a complete winding assembly.

[56] References Cited

UNITED STATES PATENTS

1,310,063 7/1919 Cummings.....336/185
1,739,246 12/1929 Majce.....336/207 X

6 Claims, 9 Drawing Figures



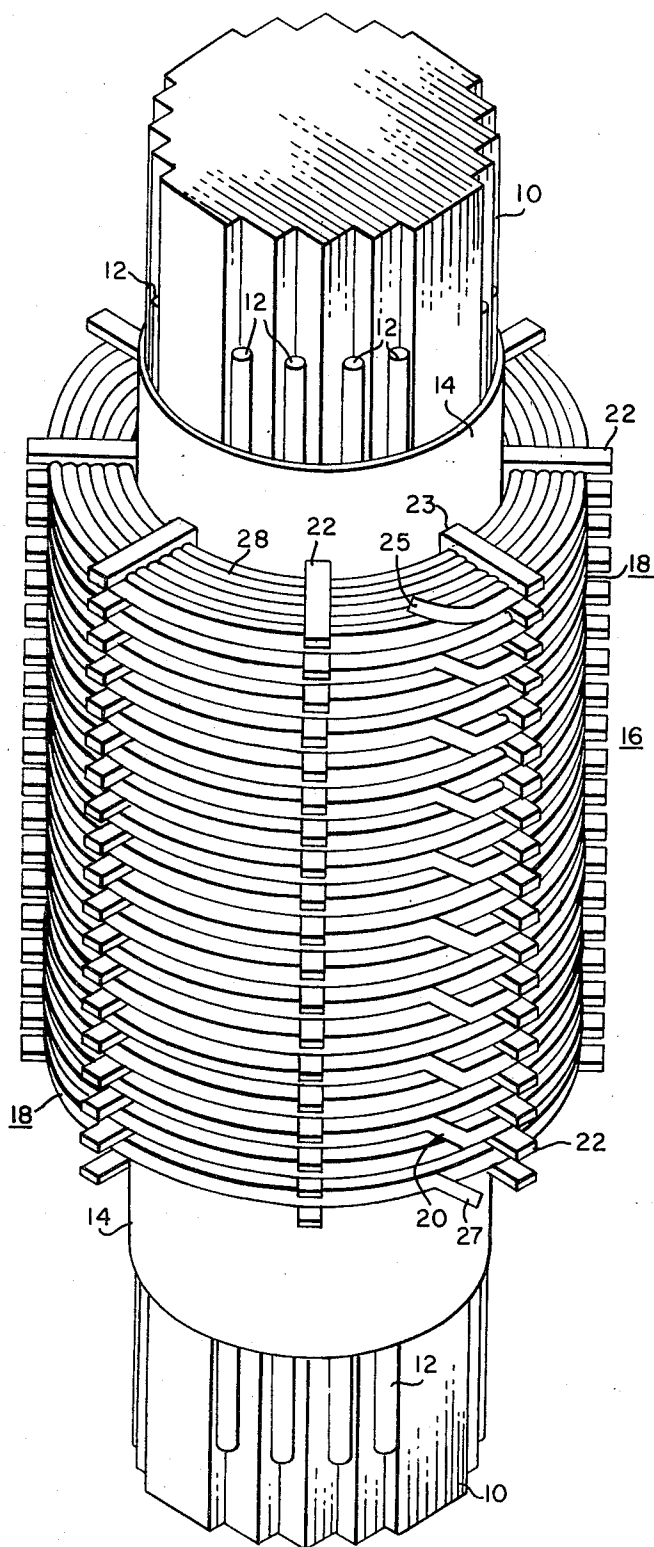


FIG. 1

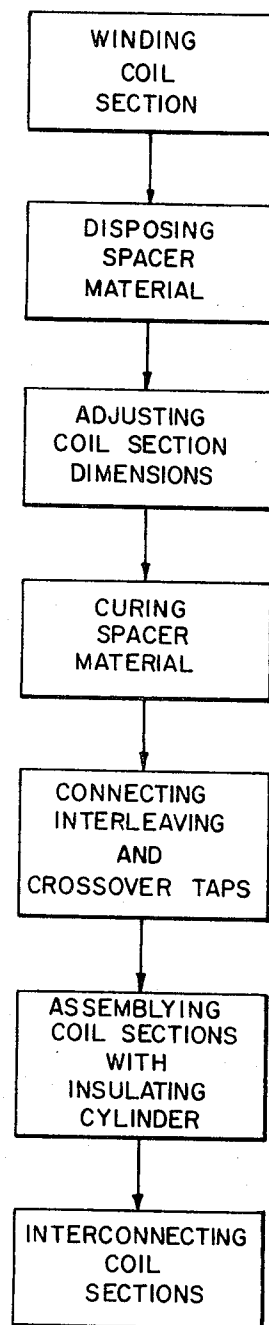
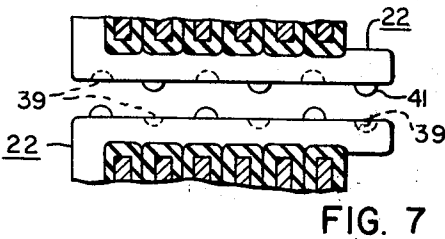
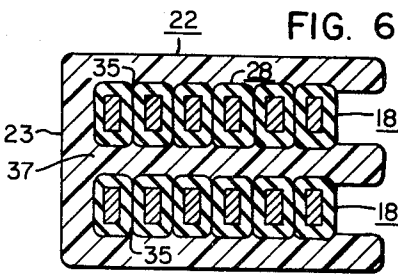
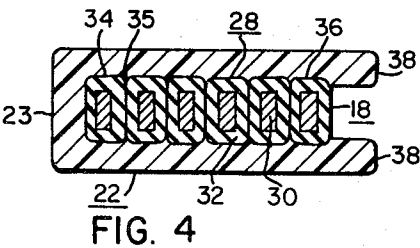
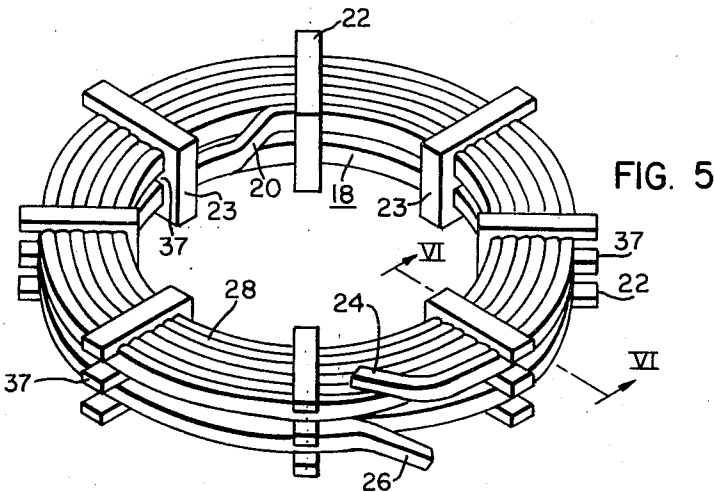
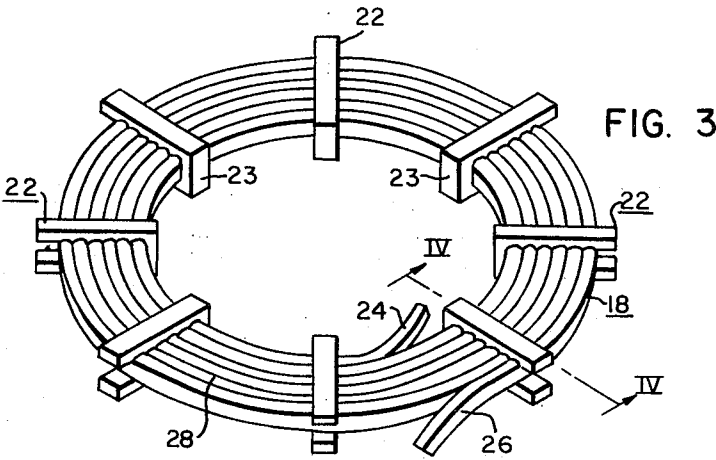


FIG. 2



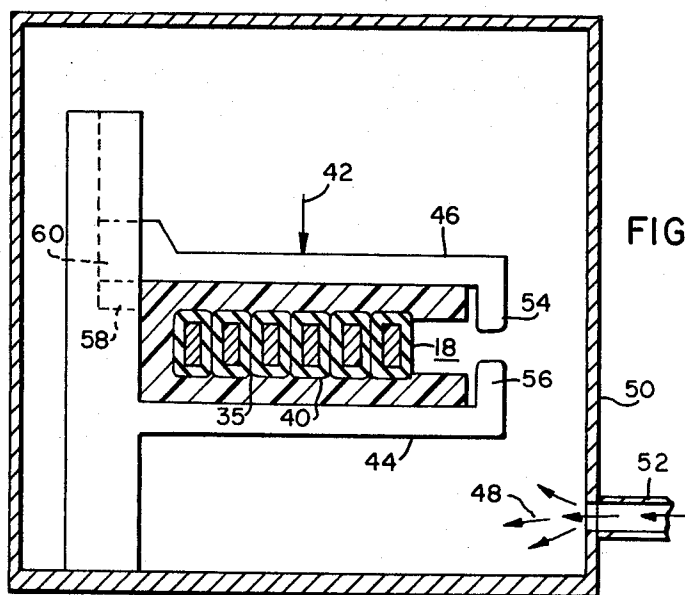


FIG. 8

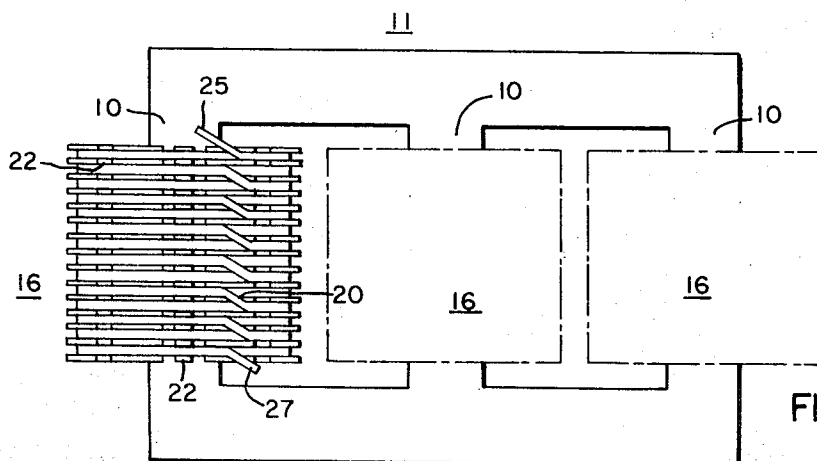


FIG. 9

METHOD OF MAKING DISK-TYPE WINDINGS FOR ELECTRICAL INDUCTIVE APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates, in general, to a new and improved winding for electrical inductive apparatus and more particularly to disk-type windings for electrical apparatus and the method of constructing same from individual sections of disk-type coils.

2. Description of the Prior Art

Certain types of power transformers of the core form type, that is, those having concentrically disposed high and low voltage windings, may have one or both of the winding structures formed from a plurality of pancake or disk-type coils. In its simplest form, the winding can be formed from a continuous conductor, that is, no brazed or welded joints are necessary within the winding. However, numerous variations in the coil type and class require that interconnections be made between the disk sections and between the conductors within the same disk. An example of a winding requiring multiple connections between disks is disclosed in U.S. Pat. No. 3,299,385, issued Jan. 17, 1967, which is also assigned to the assignee of this application.

Winding disk-type coils of the continuous conductor type is a difficult and time-consuming process. Some of the recent innovations in disk-type winding structures require that various crossover and interleaving connections be made during the winding of the coil, thus greatly increasing the manufacturing difficulties of disk-type windings. The present method of constructing disk-type windings is substantially a manual process. One or more insulated conductors are wound onto an insulated winding tube which is rotated by a mechanical means. The operator attaches the end of the conductors to the winding tube and guides them into place as the tube is rotated. The operator must guide the conductors during the winding operation so that they will be wound concentrically about the previous turn. Alternate disks of the coil must be wound, collapsed and rewound by hand, with the turns running from the outside to the inside. This is time consuming and a source of quality problems because of the extra handling of the conductors and the difficulty of obtaining a tightly rewound section. Radial spacers must be placed between the disk sections to provide adequate electrical insulation and dielectric flow between the coil sections. In some of the more complicated winding structures, interconnections between the conductors and coil disks must be made before progressing further in winding the coil.

A completed winding usually contains a plurality of disk coil sections each of which is separated by several radial spacers positioned symmetrically about the axis of the coil. Pressboard is commonly used as the spacer material due to its high dielectric strength when impregnated with the liquid coolant of the transformer. Due to the variations in the axial width of the disk and in the spacer thickness and density, windings formed from a plurality of disk coil sections do not consistently have the same overall axial height when first wound. It is necessary to adjust the dimensions of the winding so that the physical, electrical, and magnetic characteristics of the winding will meet the required specifications. This is a very time-consuming process since

spacers must be either added or removed in an orderly fashion. Each spacer must be accurately aligned so that an interlocking member can be attached to the spacers on the outside of the winding.

The present use of radial spacers with fixed dimensions inherently limits design possibilities. Since the minimum pressboard spacer thickness practicable is one-sixteenth of an inch, winding design must allow for disk spacings of one-sixteenth of an inch or multiples thereof. Although the calculated value of disk spacing may be less than an integral multiple of one-sixteenth of an inch, the designer is required to specify the larger spacing so that standard radial spacers may be used. If the designer was able to specify the actual spacing required, the distance between the disks would be reduced in some types of windings. A small reduction in disk spacing may appreciably reduce the overall height of multi-disk windings. A reduction in coil height permits reduction of core and housing size, coolant volume, and other factors dependent on coil size; therefore, a relatively small reduction in winding dimensions may substantially decrease the overall cost of the inductive device.

SUMMARY OF THE INVENTION

This invention relates to disk-type windings for electrical inductive apparatus such as power transformers. By utilizing the materials and methods taught by this invention, a substantial savings of manufacturing costs should be realized. According to this invention, the completed winding is an assembly of a plurality of coil sections. Each coil section is wound separately and then assembled onto an insulating cylinder and electrically interconnected.

A coil section comprises one or more coil disks with the turns thereof secured in place by an insulating spacer material. The teachings of this invention could be applied to coil sections with more than two coil disks but the advantages of this invention are further realized with one or two disk coil sections. Generally, every other disk of a disk-type winding is wound identically. Therefore, a coil section with more than two disks will include identical windings.

The basic coil section is wound with insulated electrical conductors according to the type and class of the completed winding assembly. Winding the coil section may be accomplished manually or automatically. The decrease in the number of turns required and the reduction in the physical size of the coil section compared to the completed winding structure makes winding by automatic or semiautomatic means more practicable.

An insulating spacer material is disposed on the conductors of the coil section after it is wound. The spacer material serves as a means to space the coil sections when they are assembled together to form a winding assembly and also as a means to securely hold the conductor turns in place. The spacer material is a suitable thermosetting resin which is cured by applying heat to the coil section. The spacer material is applied radially across the conductor turns on both sides of the coil section. If more than one disk is used in the coil section, spacer material is similarly applied between the disks. The spacer material is also applied around the inside of the disk starting turn. The spacer material in this posi-

tion assists in securing the turns in place and provides spacing between the inside turn and the insulating cylinder.

The curing process is accomplished in connection with the coil section dimension adjusting process. The coil section, with the spacer material applied, is placed into a fixture which exerts force axially on the coil section while heat is being applied to the spacer material. As the spacer material becomes plastic, it is forced into the depressions between the conductor turns. Consequently, the coil section height is reduced to a value which is governed by the forcing fixture. The fixture also forms that portion of the spacer material which covers the starting turn so that a predetermined spacing from the insulating cylinder can be maintained. When the spacer material hardens, the coil section is dimensionally constant and remains uniform.

A completed winding assembly is constructed by placing a plurality of coil sections onto a cylindrical tube and electrically interconnecting the coil sections. Interleaving and crossover connections within the coil section can be made at any convenient step in the construction process of the coil section. Axial pressure is applied to the overall winding assembly to keep the coil sections from separating.

The completed winding assembly, constructed according to the teachings of this invention, is dimensionally correct, therefore, no extra production costs are needed to size the winding and a substantial cost savings over the conventional winding method is realized.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and uses of the invention will become more apparent when considered in view of the following detailed description and drawings, in which:

FIG. 1 is an orthographic view of a magnetic core and winding assembly, with parts broken away, constructed in accordance with the teachings of this invention;

FIG. 2 is a flow chart which graphically illustrates the method used to construct the winding assembly according to the teachings of this invention;

FIG. 3 is an orthographic view of a one disk coil section constructed according to the teachings of this invention;

FIG. 4 is a sectional view taken along line IV—IV of FIG. 3;

FIG. 5 is an orthographic view of a coil section comprised of two disks and constructed according to the teachings of this invention;

FIG. 6 is a sectional view taken along line VI—VI of FIG. 5;

FIG. 7 is a sectional view illustrating a method for interlocking coil sections as taught by this invention;

FIG. 8 is an elevational sectional view illustrating a compressing fixture which may be used in constructing a coil section; and

FIG. 9 is an elevational view of a magnetic core and winding assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Throughout the following description similar reference characters refer to similar members in all figures of the drawing.

Referring now to the drawing, and FIG. 1 in particular, there is shown a winding assembly 16 constructed according to the teachings of this invention. The winding assembly 16 is shown positioned on an insulating cylinder 14, which surrounds a magnetic core 10. The magnetic core 10 may be part of an electrical inductive apparatus, such as a leg of a power transformer core. Insulating spacer rods 12 between the magnetic core 10 and the insulating cylinder 14 function as support members to prevent collapsing of the winding assembly 16 when subjected to extreme mechanical stresses.

The winding assembly 16 is comprised of separate coil sections, each of which is comprised of one or more coil disks 18. Radial spacers 22 separate each disk 18 for the purpose of providing a flow path for cooling dielectric and reducing the electrical gradient between adjacent disks. Interconnections 20 electrically connect the turns of the disks 18. The amount and placement of interconnections 20 between disks depends on the type and class of the winding assembly 16, therefore, the interconnections 20 shown in FIG. 1 are for illustrative purposes only and are not intended to restrict the scope of this invention to windings with interconnections as represented. Terminals 25 and 27 provide means to electrically connect the winding assembly 16 to the associated apparatus or circuitry, however, other terminal positions may be utilized.

The winding assembly 16 is constructed by assembling a plurality of individually constructed coil sections. FIG. 2 is a flow chart illustrating the method utilized in constructing the winding assembly 16. The insulated electrical conductor 28, shown in FIG. 1, is spirally wound to form a disk-type coil structure 18. Special classes of windings, such as interleaved and high current windings, require that more than one conductor be wound simultaneously, thus paralleling each other throughout the coil disk. This invention, as described herein, is applicable to all types and classes of disk-type windings whether wound with one or with a plurality of electrical conductors.

After the coil disk has been wound an electrically insulating spacer material is disposed on the coil disk. The spacer material may be comprised of an uncured or semicured resin, such as kraft paper pulp and phenolic resin, or of any other suitable material. The spacer material serves as the radial spacing member 22 and as a vertical spacing member 23 for the coil disk sections. If more than one coil disk 18 comprises each coil section of the winding assembly 16, spacer material must be suitably disposed on each disk 18 of the section so that adequate spacing between disks will be achieved.

FIG. 3 illustrates a coil section comprised of one coil disk and FIG. 4 illustrates the section taken along line IV—IV of FIG. 3. The insulated conductor 28 comprises a conductor 30, normally copper or aluminum, which is covered by an insulating material 32. The conductor may comprise a solid or one strand electrically conducting material, or a plurality of strands. The spacer material is applied radially around the coil disk 18 at spaced intervals. The number of spacer material dispositions is dependent on the magnitude of the electrical and mechanical stresses to which the coil section will be subjected. After the application of the spacer material, the entire coil disk section is placed into a fixture which exerts pressure on the spacer material. This

pressure forces the spacer material into the depressions 35 between the insulated conductors 28. The fixture is constructed to reduce the thickness of the spacer material a suitable amount so that the overall thickness dimension of the disk 18 substantially equals a predetermined value. That is to say that although there may be some variation of the spiral conductor section, the overall thickness of the conductors 28 and radial spacers 22 will be substantially uniform. The fixture forms the vertical spacer 23 inside the start turn 34, and the projections 38 near the finish turn 36, to produce the shape and thickness required for the particular winding being made.

The adjusting process is accomplished in connection with the curing process. Application of heat to cure the spacer material makes the spacer material plastic and its ability to change dimensions and flow into the depressions 35 between the conductors is increased. The heat is applied to the spacer material by means of heated platens, by circulating current in the conductors 28, or by high frequency dielectric heating. An infrared or hot air tunnel oven could also be used. Typical physical conditions for the adjusting and curing operation are 100 psi at 150° C for 15 minutes. After the spacer material has been cured, the coil disk 18 can be removed from the dimension adjusting fixture. Since the spacer material is hard and rigid after curing, and because it conforms to the shape of the conductor surface, the coil disk 18 maintains the dimensions established during the adjusting process. The fact that an accurate disk thickness is maintained allows assembly of a plurality of disk sections to form a dimensionally accurate winding structure without the need of additional radial spacers.

FIG. 5 illustrates a coil section comprised of two coil disks and FIG. 6 illustrates a section taken along lines VI—VI of FIG. 5. The basic procedure of construction a one disk coil section as illustrated in FIGS. 3 and 4 is utilized in constructing multi-disk coil sections, such as the two-disk section illustrated in FIGS. 5 and 6. It may be necessary to make interconnections between the disk sections, such as connection 20, during the construction of the multi-disk coil section. However, this is not essential to this invention and may be accomplished whenever convenient. The intermediate radial spacers 37 between the disks 18 may be comprised of the same material as used for the radial and vertical spacer elements. The intermediate radial spacers 37 can be disposed at discrete sections similar to the radial spacers 22, or they may be disposed continually about the radial surface of the coil disk, in the form of an insulating barrier washer. Since the disk section dimension adjustment can be accomplished by compressing the radial spacers 22, it is not necessary that the intermediate spacer 37 change dimensions during the adjusting and curing operation. However, projection of the intermediate spacer 37 into the depressions 35 between the conductors 28 of the disks 18 will improve the rigidity of the coil section. Similar material may be used for the intermediate radial spacers 37 and the radial spacers 22. A fully cured material may also be used for the intermediate spacer 37 such as Nomex paper, epoxy treated glass cloth, or kraft paper, all either with or without a coating of heat curing adhesive on one or both sides thereof.

FIG. 8 is a transverse sectional view illustrating the pertinent details of a compressing fixture which may be used in constructing the coil section shown in FIG. 4. It is understood that the fixture would be of a circular form for receiving a complete circular coil disk 18. The coil disk 18, with the spacer material 40 disposed thereon, is placed between the upper and lower plates, 46 and 44 respectively, of the fixture. The fixture is effectively enclosed within a chamber 50 which has an opening 52 therein. A heated gas 48, such as air, is forced into the chamber through the opening and heats the spacer material 40. Force is applied in the direction indicated by arrow 42 causing the upper plate to move toward the lower plate. The separation distance between the upper and lower plates is limited to a predetermined value by the dimensions of the contact areas 54, 56, 58 and 60. The separation distance must be small enough to force the spacer material into the depressions 35 and large enough to provide adequate disk spacing.

When a plurality of coil disks are included in a basic coil section, it may be necessary to electrically interconnect the discs before, during or after the adjusting and curing operation. The amount of interleaving and crossover connections depends upon the class and type of the winding structure being constructed. If the conductor leads are accessible to the outside, or finish turn area, of the disk coil section, connections could be made after the assembly of the coil sections.

The coil sections are assembled onto an insulating cylinder and the necessary electrical connections between the coil sections are made. The radial spacers 22 of adjacent coil sections contact each other, as shown in FIG. 1. An interlocking means may be formed into the radial spacers 22 to improve the rigidity of the winding assembly 16. FIG. 7 shows one type of interlocking arrangement wherein depressions 39 and protrusions 41 are formed into the radial spacers 22 so that they will engage when the radial spacers are fitted together. Various other shapes may be used. An adhesive may be applied to the radial spacers 22 to bond the coil sections together.

The winding assembly 16 is secured together in a manner similar to that used with pressboard radial spacers. Force is applied axially upon the disc sections from both ends of the winding assembly. FIG. 9 illustrates a three phase magnetic core 11 of a type which may be used in a power transformer. The winding assemblies 16 are disposed around each leg 10 of the core 11 and physically secured by a suitable means (not shown). The winding assemblies 16 are electrically connected to the associated circuitry by means such as terminals 25 and 27.

I claim as my invention:

1. A method of making disk-type windings for electrical inductive apparatus comprising:

1. winding a conductor to form a coil section comprising one or more disks;
2. disposing an electrically insulating spacer material on said coil section;
3. adjusting said coil section dimensions to conform to predetermined values;
4. curing of said spacer material to stabilize said coil section dimensions;
5. assembling a plurality of said coil sections with an insulating cylinder; and,

6. interconnecting said coil sections.

2. The method of claim 1 wherein turns of the coil section are interleaved and cross-over connections are made within said coil section.

3. The method of making disk-type windings of claim 1 wherein the spacer material is of an uncured or semi-cured resinous composition which will become plastic and flow around the conductors of the coil section during the curing process.

4. The method of making disk-type windings of claim 1 wherein the spacer material comprises kraft paper

pulp and phenolic resin.

5. The method of making disk-type windings of claim 1 wherein the spacer material is disposed radially on each disk section, and extends axially around said coil section, at incremental sections spaced about the coil section axis.

6. The method of making disk-type windings of claim 1 wherein adjusting the coil section dimensions to conform to predetermined values is accomplished by heating and compressing the spacer material.

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