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Moore

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[54] **METHOD OF CONSTRUCTING A CONTINUOUSLY TRANSPOSED TRANSFORMER COIL**

[75] Inventor: **Harold R. Moore,** Muncie, Ind.

[73] Assignee: **Westinghouse Electric Corporation,** Pittsburgh, Pa.

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[21] Appl. No.: **187,603**

[52] **U.S. Cl.** **29/605,** 140/92.2, 140/149, 242/7.08, 336/187, 336/206
[51] **Int. Cl.** **H01f 7/06**
[58] **Field of Search** 29/605; 336/206, 336/187, 69, 70; 140/92.2, 149, 71; 242/7.08

[56] **References Cited**

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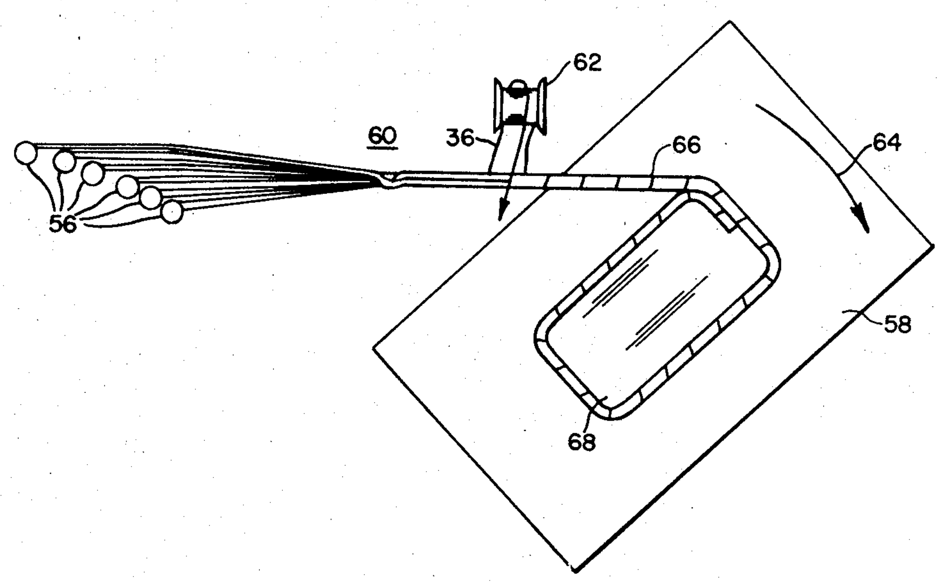
3,602,860	8/1971	Moore et al.	336/187

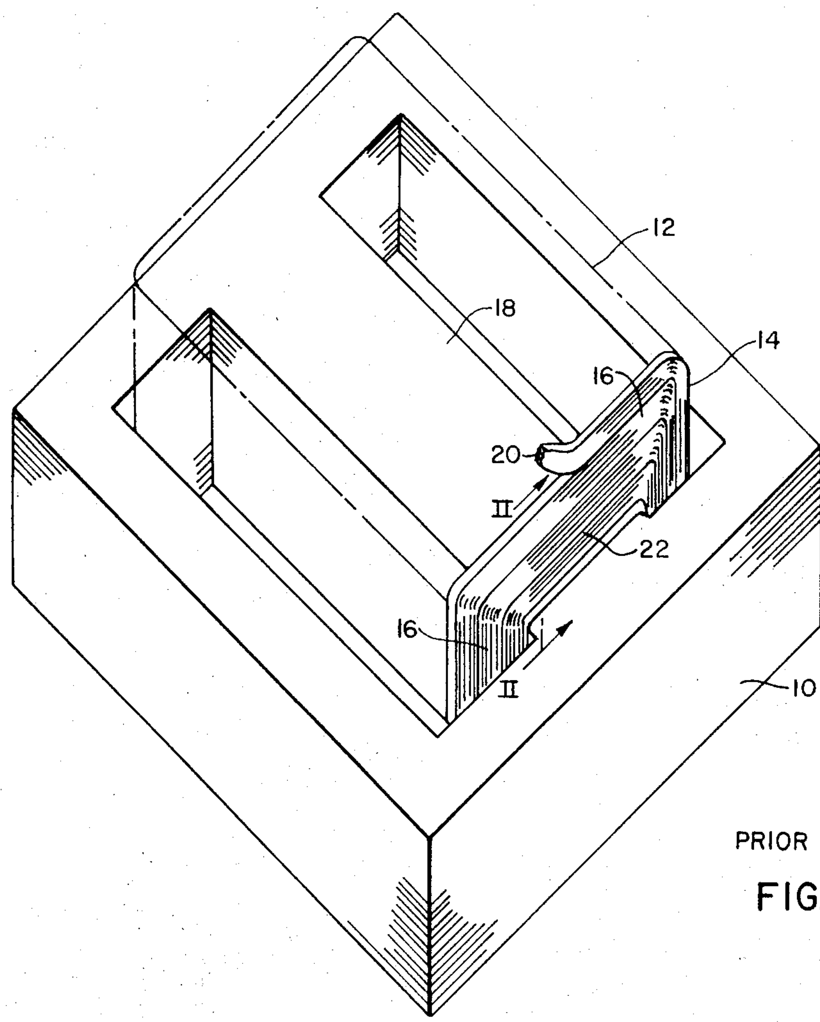
Primary Examiner—Charles W. Lanham
Assistant Examiner—Carl E. Hall
Attorney—A. T. Stratton and F. E. Browder

[57] **ABSTRACT**

Coil construction method wherein a plurality of conductor strands are transposed and then wound onto a coil form. The tranpositions are made, as the conductor is wound onto the coil form, at a position which is located between the coil form and the spools containing the strands of the conductor. Turn insulation is applied to the transposed conductor before it is wound onto the coil form. The turn insulation is flexible, thereby permitting the conductor to bend when it is wound around a corner of the coil. The turn insulation also allows the strands to slide with respect to each other while the conductor is being wound around a corner of the coil.

3 Claims, 6 Drawing Figures





PRIOR ART

FIG. 1

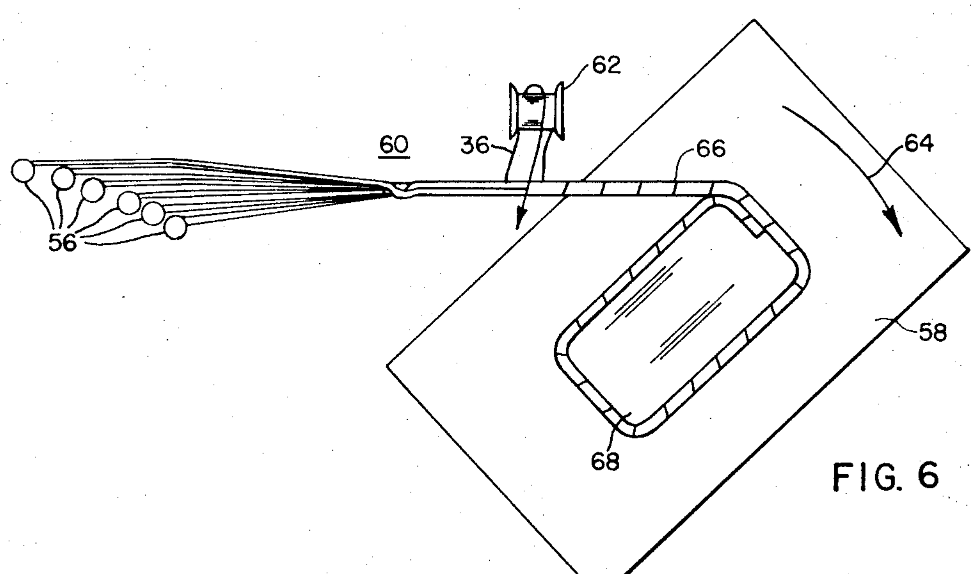
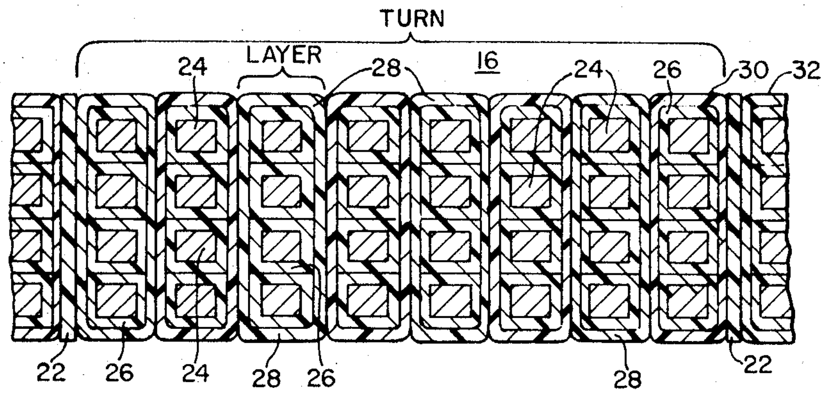


FIG. 6



PRIOR ART

FIG. 2

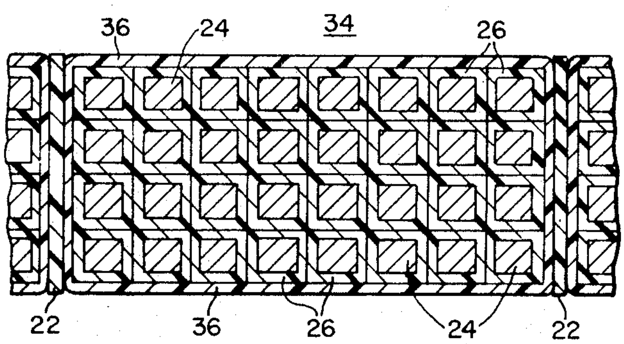


FIG. 3

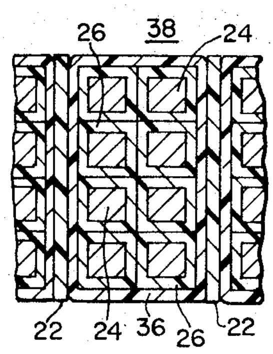


FIG. 4

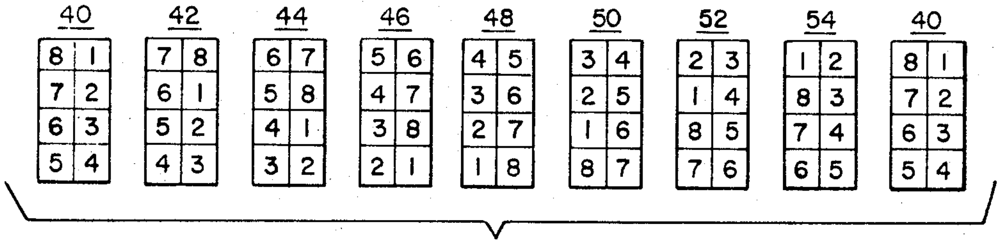


FIG. 5

METHOD OF CONSTRUCTING A CONTINUOUSLY TRANSPOSED TRANSFORMER COIL

BACKGROUND OF THE INVENTION

1. Field of the Invention:

This invention relates, in general, to electrical inductive apparatus and, more specifically, to shell-form power transformers having pancake-type coils.

2. Description of the Prior Art:

Eddy current losses in a conductor of a transformer winding are proportional to the square of the conductor dimension which is at right angles to the leakage flux. Thus, eddy current losses may be reduced by subdividing the required conductor area into two or more parallel connected conductive elements or strands, which are insulated from each other. To prevent an offsetting increase in losses due to circulating currents between the parallel connected strands, the relative position of the strands are transposed with respect to the leakage flux, in an attempt to obtain the same net flux linkages for each strand. If the parallel loops are long, the impedance of the loops aids in reducing circulating currents, but it is still important to obtain a highly efficient transposition of the conductive strands. In practice, however, ideal transpositions are impractical and undesirable circulating currents exist.

Methods for making the transpositions within the coils are described in U.S. Pat. No. 3,283,280, patented Nov. 1, 1966, and in U.S. Pat. No. 3,602,860, patented Aug. 31, 1971, both being assigned to the same assignee as this invention. However, it is desirable to distribute the transpositions throughout the conductor length, rather than lump the transpositions into a small segment of the conductor. Continuous transpositions result in better cancellation of the leakage flux, therefore it is desirable to provide a method for continuously transposing the conductor strands throughout the coil.

Continuously transposing the conductor strands involves changing the relative positions of the strands with respect to each other throughout the length of the conductor which forms the coil. Present arrangements employ a conductor formed from a plurality of strands, each individually insulated. A group of two or more strands is formed by wrapping additional insulation on a predetermined number of strands. One or more groups are then wound onto the coil form to comprise the coil conductor. It is not feasible to continuously transpose the conductor strands with this arrangement, since several strands form a group and their relative position within a group cannot conveniently be changed continuously throughout the length of the conductor. Neither is it convenient to wind each conductor strand separately, that is, without any of the strands assembled into groups, because it would be nearly impossible to keep all of the strands in place on the coil until they are bonded together by a suitable process.

Machine transposed conductors, which are first wound onto spools, are available; however, when the pretransposed conductor is wound from the spool to the coil form, the difference in the radius of the corners of the rectangular coil form tends to pull the transpositions out of place. It is desirable, and it is an object of this invention, to provide a method which may successfully be used to continuously transpose the strands of the conductor from which a rectangular pancake coil is wound.

Another disadvantage in prior art stranded conductor arrangements involves the space factor of the conductor. The strands which are adjacent to the next conductor turn must be insulated to provide adequate electrical stress protection between the strands of adjacent conductor turns. Prior art arrangements use the strand insulation as the major part of the conductor turn insulation, therefore, it must be sufficiently thick to provide the required insulation between the conductor turns. Since this provides larger than necessary insulation between the strands which are within the conductor, the space factor of the coil suffers and more insulation is used than is electrically required. Therefore, it is desirable, to provide an insulation system which will improve the space factor of a pancake coil.

SUMMARY OF THE INVENTION

Conductor strands are wound onto a substantially rectangular coil form by the rotating action of the coil form. Strand transpositions are made and turn insulation is placed around the conductor prior to the winding of the conducotr onto the coil form. The sequence of the transposing, insulating and winding operations allows the coil to be wound without the problems usually associated with winding pretransposed conductors which do not readily permit the necessary strand slippage. A high density crepe paper insulation is used for the turn insulation so that the strands will slip and the conductor will flex during the winding operation. The turn insulation eliminates the need for layer insulation, thereby improving the space factor of the coil.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a view of shell-form magnetic core with its associated winding structure shown in phantom and constructed according to the prior art;

FIG. 2 is a partial sectional view of the coil shown in FIG. 1 taken along the line II—II;

FIG. 3 is a partial sectional view of a coil constructed according to this invention illustrating the insulation system for a coil conductor having the same number of strands as shown in the prior art system of FIG. 2;

FIG. 4 is a partial sectional view of a coil constructed according to this invention having eight strands;

FIG. 5 is a schematic representation of a strand transposition sequence; and

FIG. 6 is a view illustrating the operations in winding a coil as taught by this invention.

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 shell-form laminated magnetic core **10** with a winding structure **12**, shown in phantom, disposed in inductive relationship with the magnetic core. A disk-type or pancake coil **14**, which is part of the phantom winding structure **12**, comprises a stranded conductor **16** which is spirally wound around the center leg **18** of the magnetic core **10** and radially disposed on the adjacent turns of the coil. The coil lead **20** may be connected to another coil or to bushings on the transformer casing, which are not illustrated. Insulated turn spacers **22** are placed between the turns of the coil to facilitate winding and improve the coil-to-coil insulation.

FIG. **2** shows a partial cross-sectional view taken along the line II—II of the coil **14** which is shown in FIG. **1.** A single turn of the conductor **16** comprises all of the strands **24** which occupy the space between two adjacent turn spacers **22.** Each strand **24** of the conductor is individually insulated by the strand insulation **26.** The strands are grouped into layers of four strands and insulated with the layer insulation **28.** The conductor **16** comprises 32 individually insulated strands and eight individually insulated layers. Numerous other strand and layer arrangements have been used in the prior art, however, the arrangement illustrated in FIG. **2** is typical in that most of the arrangements have had individually insulated strands with several strands grouped and insulated to form layers.

The greatest electrical stress occurs at a region between an end layer of a turn and the adjacent end layer of the adjacent turn. In FIG. **2,** such a region would exist between the strand layers **30** and **32.** Since the turn spacer **22** is only a minor part of the adjacent turn insulation, the strand and the layer insulation **26** and **20,** respectively, must be sufficiently thick to prevent dielectric breakdown. With the prior art insulation arrangement shown in FIG. **2,** the required insulation between the turns, which is determined by the stress between the coils, makes it necessary to have more insulation between the other layers of the turn than is electrically needed. This degrades the space factor of the coil, and ultimately increases the size and cost of the transformer.

FIG. **3** illustrates an insulation arrangement as taught by this invention to improve the space factor of the coil and to make continuously transposed conductors feasible. The improved space factor arrangement is feasible from overall construction considerations since this arrangement permits continuously transposing the strands throughout the conductor, as will be hereinafter described. The conductor **34** comprises the strands **24** and the strand insulation **26,** similar to that described concerning FIG. **2.** The strand insulation **26** may be a cellulose material, an enamel applied to the strands, a noncellulose material such as Nomex, or any other suitable suitable strand insulating material. It is desirable that the strand insulation **26** be formulated or coated with a suitable material so that adjacent strand insulation surfaces may be bonded together after the coil has been wound. For example, the insulation may contain a thermosetting plastic resin which will bond the coil together when it is heated after winding.

The entire conductor **34** is covered with turn insulation **36** which helps provide adequate electrical stress protection between the conductor turns and helps secure the strands in position during the winding operation. The turn insulation **36** may comprise any suitable material, such as high density crepe paper, which is flexible and which will permit the strands to slip during the winding operation. By covering the conductor with the turn insulation **36,** excessive insulation is removed from between the individual strands and the space factor of the coil is improved. The turn insulation **36** keeps the strands **24** properly positioned in the conductor **34** during the winding of the coil. Since the turn insulation **36** is applied when the conductor is substantially straight, it must also flex with the curvature of the conductor when wound around the corners of the coil form. The strands **25** of FIG. **3** are not wound in individually insulated layers as the strands of FIG. **2.** The conductor turn shown in FIG. **3** comprises a plurality of insulated strands, all of which are enclosed by the turn insulation **36.**

The number of strands required in a conductor is dependent largely on the current requirements of the coil. The invention as described herein may be used with shell-form transformer coils having strand numbers different than that shown in FIG. **3.**

FIG. **4** illustrates a conductor **38** having eight individually insulated strands **24,** with all of the strands insulated with the turn insulation **36.** With this eight-strand arrangement, the strands would be transposed at predetermined intervals throughout the length of the conductor. Preferably, a transposition would be made at conductor length intervals equal to one-eighth of the conductor length, or more often when desired. This assures that each strand will occupy every strand position within the conductor for one-eighth of the conductor length.

FIG. **5** schematically illustrates the transposing sequence discussed in connection with FIG. **4.** The conductor cross-sections **40, 42, 44, 46, 48, 50, 52** and **54** are taken at intervals throughout the conductor length equal to one-eighth of the conductor length. It can be seen from the position of the strand numbers that each strand occupies a different strand position for one-eighth of the conductor length. Consequently, each of the eight strands links the same amount of flux over the entire conductor length. Other transposition sequences may be used without departing from the scope of the invention. Different numbers of strands may comprise the conductor and more or less than four axially adjacent strands may be arranged to form the conductor cross section.

FIG. **6** illustrates a method of constructing a shell-form transformer coil as taught by this invention. The strands, which are individually insulated, are pulled from container means, such as the spools **56,** by the rotary motion of the winding table **58.** The strands are suitably transposed at position **60.** The turn insulation **36** is drawn from a container means, such as the bobbin **62,** and wrapped around the conductor strands. As the winding table **58** rotates in the direction illustrated by the arrow **64,** the conductor **66** is wound onto the substantially rectangular coil form **68.** When the conductor **66** is wound around a corner of the coil form or a corner of an adjacent turn, the strands must slip with respect to each other. This invention permits the necessary slippage by wrapping the conductor with a turn insulation material which allows the strands to slide therein. As they slide, the spools **56** pay out more or less strand length as required. With this method, the transposition is not pulled out of place nor does the conductor **66** have a tendency to bend out of shape.

The operations may be performed continuously or the machinery may be stopped during the process. For instance, the winding table rotation could be stopped while the transposition is made manually, then the winding table would be started and would rotate until the next transposition is to be made. Minimum strand slippage sould be obtained when the conductor **66** is nearly all of the way around the corner of the coil when the winding table is stopped and the transposition is made.

By making the transpositions prior to the winding of the conductor, and by wrapping the conductor with suitable turn insulation just before the conductor is wound onto the coil form, coils having continuously transposed conductors may be successfully manufactured. Since numerous changes may be made in the above described method and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all of the matter contained in the foregoing description or shown in the accompanying drawings shall be interepreted as illustrative rather than limiting.

I claim as my invention:

1. A method of constructing a pancake type coil for shell-form transformers comprising the operations of:

winding a plurality of conductor strands from spools onto a substantially rectangular coil form, said winding operation being performed by rotating the coil form;

stopping the winding operation by stopping the coil form rotation when the conductor strands are nearly all of the way around a corner of the coil form;

transposing at least one of the strands to a different position relative to the other strands in the conductor;

starting the winding operation by starting the rotation of the coil form;

wrapping a solid insulating material collectively around the plurality of conductor strands,, said solid insulating material having a composition which permits slippage of the strands when the conductor having a composition being wound around a corner of the coil form;

continuing said winding operation with at least some of said strands slipping with repsect to each other and said insulating material when they are wound around a corner of the coil form;

said transposing operation being performed at a position which is located between the coil form and the strand spools and said wrapping operation being performed at a position which is located between the transposing position and the coil form.

2. The method of contructing a coil of claim 1 wherein the solid insulating material comprises high density crepe paper tape.

3. The method of constructing a coil of claim 1 wherein the operations are repeated a sufficient number of times to permit each strand of the conductor to occupy, for part of the conductor length, each of the various positions which the strands may occupy in the conductor.

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