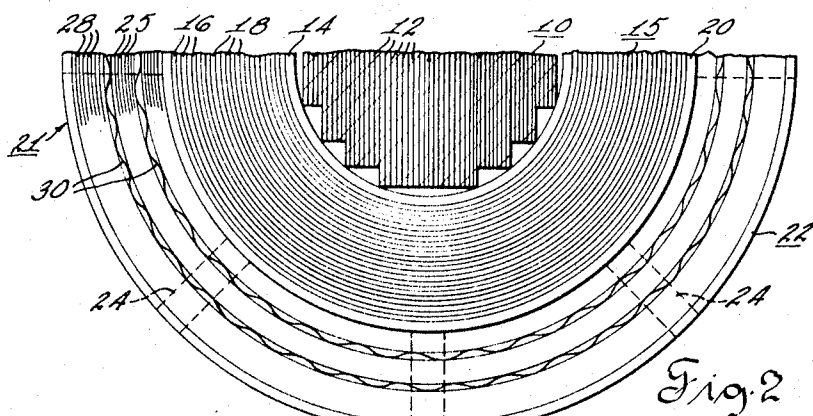
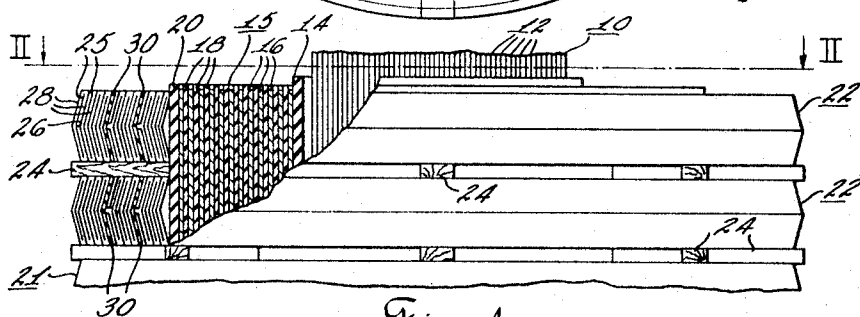
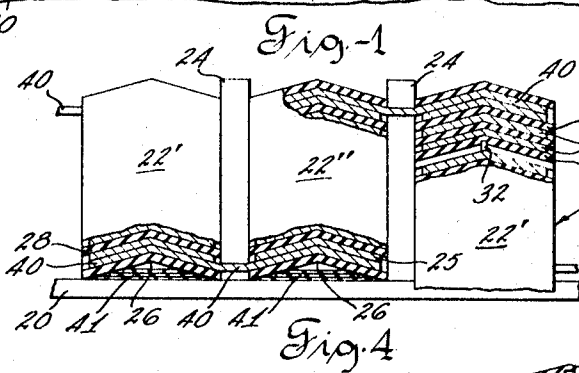
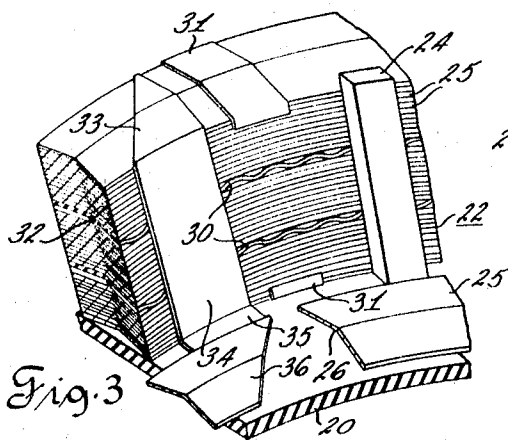
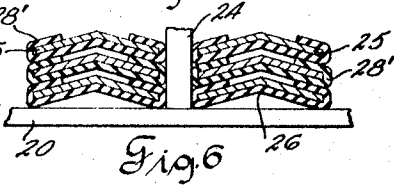


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CONDUCTOR STRIP TRANSFORMER WINDING HAVING
IMPROVED SHORT CIRCUIT STRENGTH
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CONDUCTOR STRIP TRANSFORMER WINDING HAVING IMPROVED SHORT CIRCUIT STRENGTH

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5 Claims

ABSTRACT OF THE DISCLOSURE

An electrical transformer winding having high short circuit strength comprises a plurality of coaxial, axially spaced disk coils of one-turn-per-layer connected in series and spirally wound from wide conductor strip having a longitudinal depression therein so that the turns interlock with each other to prevent axial movement. Flexible strip insulation wider than the conductor strip is wound between conductor strip turns and bent in conformity with the longitudinal depression by the tensioned conductor strip turns. Corrugated support members wound at radially spaced points between the conductor strip turns of each disk coil provide cooling ducts in an axial direction and have a longitudinal saw cut therein so that they conform to the longitudinal depression in the conductor strip turns. The corrugated support members are as wide as the strip insulation and abut against radial spacers on both sides of each disk coil and have high compressive strength when held between the tensioned conductor strip turns and prevent axial movement of the disk coils and crushing of the insulation strip.

This invention relates to stationary induction apparatus such as transformers for electrical power systems and in particular to high voltage windings for such apparatus.

Primary windings for electrical transformers are often of the helical coil, or barrel coil, type wherein wire conductor is helically wound in concentric layers with insulation sheets between layers having radially extending folded end portions, termed "keepback" insulation, to provide mechanical support for the wire turns in an axial direction and to increase the breakdown strength between layers and between winding sections. Primary windings for higher voltage transformers are often of the disk coil, or pancake coil, type and may have one conductor turn per layer in each disk coil and a plurality of axially spaced disk coils arranged in a stack with radial insulating spaces between disk coils. Adjacent disk coils are usually wound in opposite directions so that their starts and their finishes can be connected together, but "break voltage" disk coils are occasionally used wherein adjacent disk coils are both wound from the inside out and the radially outer turn of one coil is connected to the radially inner turn of the adjacent disk coil.

Transformer secondary windings wound from wide conductor strip are known, but the greater number of turns of smaller cross sectional area conductor required to provide the desired reactance in the primary windings has heretofore prevented construction of strip wound transformer primary windings of sufficient short circuit strength to meet industry standards.

It is an object of the invention to provide an improved transformer conductor strip winding which eliminates the folded keepback insulation and is cheaper in cost and simpler in construction than prior art structures.

It is a further object of the invention to provide an improved transformer primary winding of wide strip conductor which has high short circuit strength and can be

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constructed either with adjacent disk coils wound in opposite directions or with "break voltage" coils.

These and other objects and advantages of the invention will be more readily apparent from the following detailed description when considered in conjunction with the accompanying drawing wherein:

FIG. 1 is a partial plan view, partly in section, of a transformer core and coil assembly embodying the invention;

FIG. 2 is a partial view taken along line II—II of FIG. 1;

FIG. 3 is a perspective view showing the crossover connections between adjacent disk coils of FIG. 1 when "break voltage" construction is utilized, an embodiment being shown wherein the conductor strip of the primary winding has an insulating coating thereon;

FIG. 4 is a partial view similar to FIG. 1 showing crossover connections between adjacent disk coils when the adjacent coils are wound in opposite directions and the conductor strip is folded out to provide the crossover connections;

FIG. 5 is a cross sectional view of one of the corrugated insulating support members provided at radially spaced points between turns of each of the disk coils to provide cooling ducts and high mechanical strength in an axial direction against short circuit forces; and

FIG. 6 illustrates an alternative embodiment of the invention.

Referring to FIGS. 1 and 2 of the drawing, a transformer core and coil assembly includes a closed magnetic core 10 having a straight winding leg constructed from a plurality of magnetic steel laminations 12 of different widths to provide a cruciform cross section. An insulating tube 14 surrounds the winding leg of core 10, and a transformer secondary strip winding 15 wound on insulating tube 14 comprises a plurality of spiral turns 16 of wide conductor such as copper or aluminum sheet. Secondary winding 15 can either have interlayer insulation such as paper sheet 18 between spiral turns or the sheet conductor can have a suitable insulating coating (not shown) of sufficient dielectric breakdown strength to withstand turn-to-turn voltage under impulse conditions, for example, an epoxy resin or an acrylic resin coating on aluminum sheet. Further, the sheet conductor can either extend substantially the entire axial length of the transformer winding, or several axially spaced conductor sheets can be spirally wound simultaneously in each layer to provide the desired secondary winding characteristics. A tubular "high-low" insulating barrier 20 in conventional manner surrounds the secondary winding 15 and isolates it from the radially outer transformer primary winding 21 which preferably is axially shorter than secondary winding 15 and comprises a plurality of axially spaced disk coils 22 each having one turn per layer. Radially extending insulating spacers 24 are disposed at circumferentially spaced positions between adjacent disk coils 22.

Each disk coil 22 comprises a plurality of spiral turns 25 of sheet or strip conductor such as aluminum strip having a width in the axial direction many times greater than its thickness in the radial direction and having a longitudinal depression 26 so that adjacent turns interlock with each other and are prevented from moving in a direction axial of the coil. Interlayer insulation 28 of suitable material such as paper strip may be wound between conductor strip turns 25 simultaneously with the winding of the conductor strip as shown in FIGS. 1, 2 and 4 and assumes the depressed contour of the conductor strip cross section and extends beyond the edges of the conductor turns 25 to increase the creep distance and breakdown strength between turns and also between adjacent disk coils 22. In a typical kva. transformer having

a rated primary potential of 7620 volts, the aluminum strip conductor may be .010 inch thick and three inches wide and the paper insulation may extend $\frac{1}{4}$ inch beyond the edges of the strip conductor. The strip conductor is illustrated in the drawing as being of V-shaped cross section, but it will be appreciated that any contour of longitudinal depression may be utilized which provides an interlocking cross section of strip conductor that prevents relative movement between adjacent conductor turns. For example, the strip conductor may be of arcuate cross section, or the longitudinal depression 26 in the conductor strip may be of arcuate cross section.

The longitudinal depression 26 can be easily formed in the conductor strip by pulling the conductor strip over a cylindrical roller (not shown) having an outer surface similar to the desired interlocking strip cross section as the strip is being wound and to wind the strip with sufficient tension to cause the flat strip to assume the contour of the roller surface as it passes over the roller. For example, the inverted V-shaped cross section of conductor strip illustrated in the drawing is easily formed by pulling thin, flat aluminum strip across a cylindrical roller having an outer surface with a raised circumferential rib (not shown) positioned centrally of its axial length. The tension with which the conductor turns 25 are wound assures mating of the interlocking across sections of adjacent conductor strip turns 25 and thereby prevents movement of the conductor strip turns 25 relative to each other and also prevents movement thereof relative to the paper turns 28, thereby assuring that the creepage distance, formed by the width of paper turns 28 extending beyond the conductor strip turns 25, is not decreased under short circuit conditions. The longitudinal depression 26 in the conductor turns 25 assures that no change occurs in the centering of the conductor strip and paper strip under short circuit conditions and thus prevents variations in electrical characteristics of the primary winding resulting from lateral movement of the paper strip relative to the conductor strip.

A plurality of axially spaced support means 41 (see FIG. 4) may be provided on tubular insulating barrier 20 to mate with the longitudinal depression 26 and prevent flattening of the inner conductor strip turns 25 of each of said disk coils 22 to insure against their movement in an axial direction, and each such support means 41 may comprise several layers of tapered tape gradually diminishing in width in a longitudinal direction wound on tubular barrier 20, as shown in FIG. 4 of the drawing, or may comprise a plurality of turns of string (not shown) wound on barrier 20, or such plurality of support means may be machined or otherwise formed on barrier 20.

The preferred embodiment of the invention is illustrated and described as having circular coils 15 and 21 surrounding a magnetic core 10 of cruciform cross section, but the invention is also applicable to windings and magnetic cores having cross sections other than circular such as rectangular coils and cores of rectangular cross section. The conductor strip turns 25 having the longitudinal depression 26 therein tend to flatten at the sharp corner radii of a rectangular winding, but any such spreading of the conductor strip in an axial direction at the corners does not adversely affect the structure since the radial spacers 24 are positioned along the flat sides of the coil rather than at the corners.

The edges of the paper turns 28 extending beyond the edges of the strip conductor turns 25 do not have sufficient mechanical strength to prevent movement of the disk coils 22 in an axial direction under short circuit forces. Support means for preventing axial movement of disk coils 22 and for preventing crushing of the edges of the paper turns 28 extending beyond the conductor turns 25 may comprise elongated corrugated insulation support spacers 30 wound at radially spaced points between conductor turns 25 and having a longitudinal saw cut 32

(see FIG. 5) midway of their axial dimension so that they can be bent to and assume the V-shape cross sectional contour of the strip conductor turns 25. The corrugated support spacers 30 provide axially extending cooling ducts for the circulation of insulating dielectric liquid (not shown) in which the transformer core and coil assembly is immersed. The corrugated support spacers are preferably of a relatively thick insulating material such as $\frac{1}{8}$ inch vulcanized fiber and extend axially to the edges of paper strip turns 28 and abut against the radial spacers 24 between disk coils 22. The spiral conductor strip turns 25 are wound with sufficient tension to bend the paper strip 28 and the support spacers 30 in conformity with the V-shape cross section of the conductor strip, and suitable anchoring means 31 are applied to the inner turn and to the outer turn of each disk coil 22 to hold the conductor strip turns in interlocking engagement and the paper strip and support spacers in conformity with the V-shape cross section of the conductor strip. Although bent to V-shape cross section, the corrugated spacers 30, when held between tensioned turns 25 of conductor strip, have high mechanical strength against deformation in an axial direction, and since they abut against the radial spacers 24, the corrugated support spacers 30 prevent movement of the disk coils 22 in an axial direction and thus prevent deformation of the edges of the interlayer paper turns 28 and consequently prevent change of electrical characteristics of the primary winding due to displacement of the disk coils 22 under short circuit conditions.

FIG. 3 illustrates a "break voltage" arrangement wherein all of the disk coils 22 are wound from the inside out and the conductor strip is continuous from one disk coil to the next and provides the crossover connection between adjacent disk coils. The outermost turn 25 of conductor strip is illustrated as having a folded portion 33 extending at right angles to the longitudinal axis of the turn and axially of the coil, a bent over portion 34 at right angles to the folded portion 33 and extending inward radially of the coil to the innermost coil layer, another bent portion 35 at right angles to the portion 34 and extending axially of the coil, and a second folded portion 36 extending circumferentially of the coil and forming the radially inner conductor strip turn of the adjacent disk coil 22. It will be appreciated that insulation members (not shown) surround the portions 34 and 35 of conductor strip which define the crossover connection between the adjacent disk coils 22. This arrangement permits all disk coils 22 to be constructed while the winding mandrel is rotated in the same direction.

FIG. 4 illustrates a construction wherein adjacent disk coils 22 are wound in opposite directions and extra lengths of conductor strip 40 at the ends of the radially inner and radially outer turns of alternate, e.g., odd numbered, disk coils 22' are folded in an axial direction and secured to the corresponding conductor turns of adjacent even numbered disk coils 22'' wound in the opposite direction to provide crossover connections between adjacent disk coils. This construction requires winding alternate, e.g., odd numbered disk coils 22, while the winding mandrel is rotated in one direction and then reversing the winding mandrel and winding even numbered disk coils while the winding mandrel is rotated in the opposite direction. In an alternative embodiment (not shown) separate pieces of conductor strip are secured to the start conductor turns of one pair of adjacent disk coils 22 and to the finish conductor turns of the next pair of adjacent disk coils to provide the crossover connections between oppositely wound disk coils 22.

The paper strip insulation between conductor turns 25 of the disk coils 22 is omitted in FIG. 3 of the drawing to simplify the disclosure and facilitate the understanding of the invention, but it will be appreciated that this figure also illustrates an alternative embodiment of the inven-

tion wherein the conductor strip, for example, aluminum strip, has an insulating coating such as epoxy resin, an acrylic resin or an imide resin, thereon, the interlayer paper insulation 28 is omitted, and the spiral conductor turns 25 having an insulating coating thereon touch.

In the alternative embodiment of the invention illustrated in FIG. 6, the conductor strip having the longitudinal depression 26 therein is wrapped in an envelope of paper insulation 28' as the conductor turns 25 are wound on tubular barrier 20, and such envelope of insulation covers the edges of the conductor strip and insulates between adjacent disk coils 22.

While only a few embodiments of the invention have been illustrated and described, many modifications and variations thereof will be readily apparent to those skilled in the art, and consequently it is intended in the appended claims to cover all such modifications and variations which are within the true spirit and intent of the invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In an electrical transformer coil, a winding section comprising a plurality of coaxial, axially spaced disk coils of one turn per layer electrically connected in series and wound so that the magnetic flux generated in all of said coils is in the same direction, said disk coils being spirally wound of conductor strip having a width in the axial direction considerably greater than its thickness in the radial direction and being of such a cross section that adjacent spiral conductor turns interlock with each other to prevent axial movement thereof, flexible strip insulation wound between adjacent conductor strip turns and being wider in an axial direction and extending beyond the edges of said conductor strip, said spiral conductor strip turns of each disk coil being wound with sufficient tension to bend said flexible strip insulation in conformity with said cross section of said conductor strip and maintain each said conductor strip turn in continuous engagement with the strip insulation turn radially inward therefrom, anchoring means in each disk coil for holding the conductor strip turns thereof in said spirally wound interlocking relation, radial insulating spacers between adjacent disk coils, and insulating support members having a width in the axial direction at least equal to that of said insulation strip disposed at radially spaced positions between said conductor strip turns of each disk coil and conforming to said conductor strip turns in the longitudinal direction and to said conductor strip cross section in the transverse direction and abutting at their opposite edges against said radial insulating spacers on both sides of said disk coil and preventing crushing of the portions of said insulation strip extending beyond said conductor strip under short circuit conditions on said transformer coil.

2. In an electrical transformer coil in accordance with claim 1 wherein said support members are flexible and said conductor strip turns are wound with sufficient tension to flex said support members in conformity with said conductor strip cross section and wherein said support members have high compressive strength in the axial direction when held in conformity with said conductor strip cross section between adjacent conductor strip turns so restrained under tension by said anchoring means.

3. In an electrical transformer coil in accordance with claim 2 wherein said support members are elongated and corrugated and sufficiently flexible in a longitudinal direction to be wound between adjacent conductor strip turns and define ducts for circulation of a cooling dielectric liquid in an axial direction between said adjacent conductor strip turns.

4. In an electrical coil in accordance with claim 3 wherein said conductor strip has a longitudinal depression defined by a pair of opposed surfaces one of which bulges outwardly and the other of which is complementary to said one surface and said support members have longitudinal grooves permitting bending thereof in conformity with said pair of opposed surfaces of said conductor strip and wherein said conductor strip turns are wound with sufficient tension to bend said support members in conformity with said pair of opposed surfaces of said conductor strip turns wherein they are held by said anchoring means.

5. In an electrical coil in accordance with claim 4 wherein said conductor strip is of V-shaped cross section and said support members have a longitudinal slot midway of the width thereof protruding partially through the thickness thereof.

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