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[54] **RESIN IMPREGNATED TRANSFORMER COIL ASSEMBLY**

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[52] **U.S. Cl.** **336/205,** 336/206, 336/223

[51] **Int. Cl.**.....**H01f 27/32**

[58] **Field of Search**.....336/96, 205, 206, 223; 174/25 PE, 108, 109

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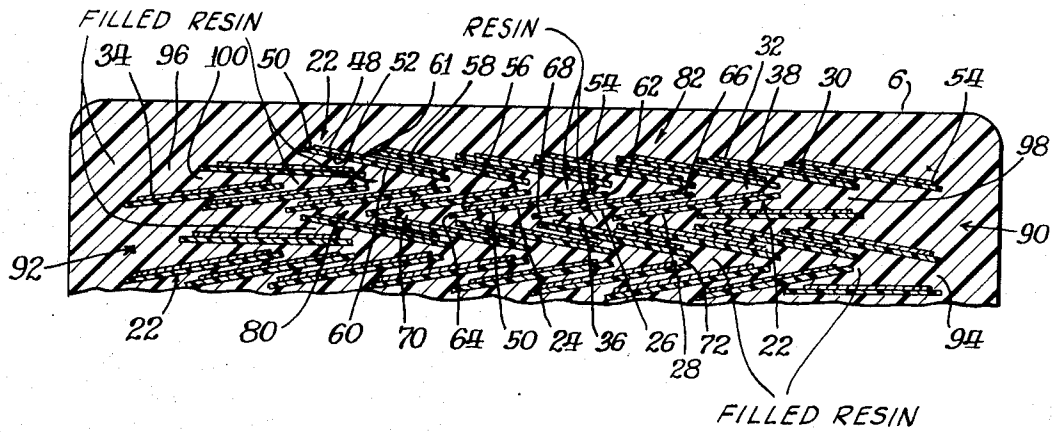
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[57] **ABSTRACT**

A transformer coil assembly having a strip conductor wound to form a plurality of helix-shaped winding layers positioned concentrically and impregnated and encapsulated with a solidified unitary resinous mass. The strip conductor has a strip of conductive material and a strip of insulative material engaging one of the faces of the conductive strip and extending beyond both edges of the conductive strip which separates and electrically insulates adjacent turns in a layer and adjacent layers from each other. The resinous mass includes a filler which is unevenly distributed within the resin such that pure resin is in the smaller interstices of the coil, between turns in a layer and between turns of adjacent layers and a resin and filler in the larger interstices of the coil and encapsulating the coil.

4 Claims, 4 Drawing Figures



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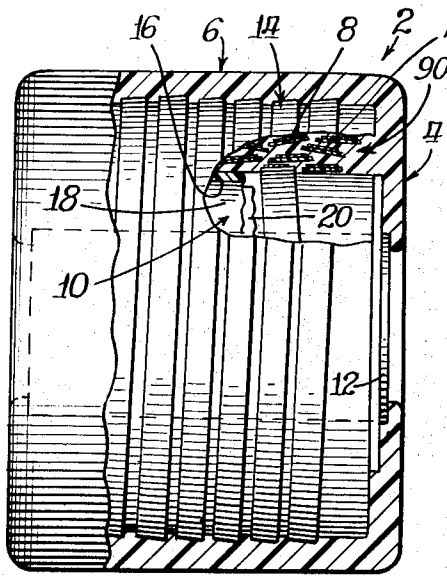


Fig. 1.

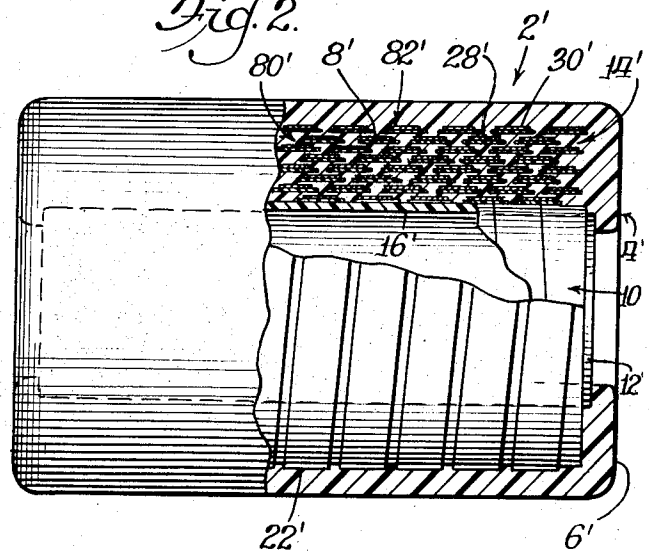


Fig. 2.

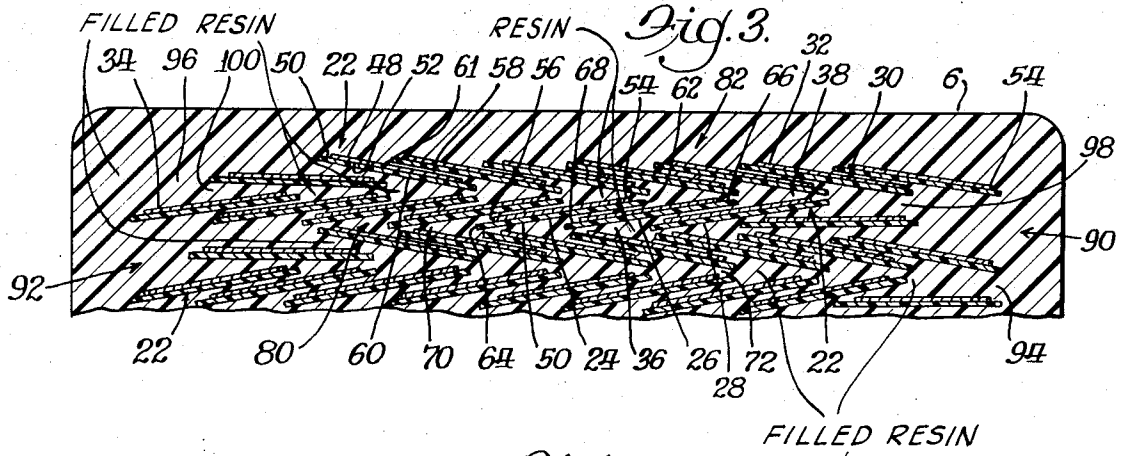


Fig. 3.

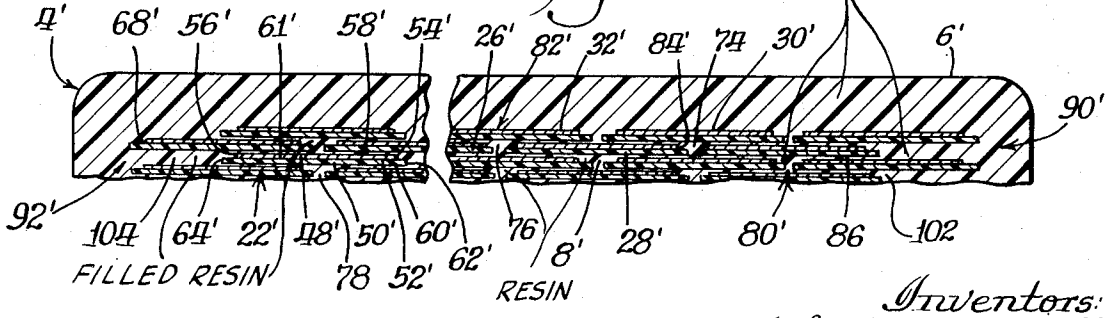


Fig. 4.

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RESIN IMPREGNATED TRANSFORMER COIL ASSEMBLY

BACKGROUND OF THE INVENTION

This invention relates to an electrical coil, and, in particular, to a resin impregnated strip conductor coil for a transformer.

In recent years, transformer windings wound from strip or foil conductive material have became increasingly popular due to the ease with which strip material may be wound. The two most common types of strip windings are the full width foil type winding and the narrower spiral type strip winding. The full width foil type winding extends the complete width of the transformer winding and, because of its width, is of a very thin material. A particularly thin foil is used for high voltage windings where the current requirements and the foil cross sectional area requirements are small. Use of a very thin foil in high voltage windings results in winding problems caused by the low tensile strength of thin foil and defects in the foil due to manufacturing problems inherent in producing thin foil. Further, since each foil layer in a winding must be electrically insulated from adjacent foil layers, a high amount of insulation space relative to the conductor space is required, i.e., a low space factor results.

A plurality of spiral type strip windings may also be utilized and such windings are particularly desirable where smaller cross sectional areas are required. Such windings typically have a strip conductor shape which is narrower and thicker than thin foil material and which is more economical. Spiral windings are generally positioned in a side by side relationship with their ends brought out and connected together to form the desired winding arrangement. Due to their narrowness, spiral coils have low mechanical strength which tends to cause axial collapse when mechanically stressed. As a consequence, insulative material must be wedged between the sides of the coils to maintain them in position. Addition of insulative material, of course, reduces the space factor of the over-all windings. In addition, the bringing out and connecting of the ends of the spiral windings creates further stress problems and increases the cost of the winding assembly.

Impregnation and encapsulation of electrical coils with a resin is well known in the art as a means of providing both electrical insulation and mechanical support of the coil. There are, however, several problems which arise when resin is utilized in this manner. First of all, a thorough impregnation of the coil even into its most remote coil interstices is often difficult due to lack of flow paths for the resin. A further problem that occurs is the cracking of the resin where it adheres to or grips the outer surface of the coil, particularly where resin alone is used to impregnate the coil and a filled resin for greater mechanical strength is used to encapsulate the coil. Where either of the foregoing problems occur, there is both loss of mechanical strength and opportunity for corona discharges.

SUMMARY OF THE INVENTION

It is a general object of the invention to provide a resin impregnated electrical coil assembly having a strip type conductor which maximizes the space factor and mechanical strength of the coil and which is particularly suitable for impregnation and encapsulation by a resin to provide further mechanical strength and electrical insulation.

The objects of the invention are accomplished by winding a flat conductor having an insulative strip and a conductive strip narrower than and spaced from the edges of the insulative strip to form a plurality of winding layers each having a plurality of axially displaced turns in a layer insulated from each other and from turns in adjacent layers by the insulative strip material. The resulting winding provides a number of resin flow paths so that the finished coil assembly has solidified resin even in the smallest interstices of the coil and between the turns in the same layer and between turns in adjacent layers and the end faces of the coil present a very uneven surface which is tightly gripped by the outer solidified resin. The objects of the invention are accomplished by winding a flat conductor in a traverse winding configuration and impregnating and encapsulating the resulting coil with a resinous material. The flat conductor comprises a conductive strip engaging an insulative strip extending beyond both edges of the conductive strip. The traverse winding of the coil comprises a plurality of winding layers alternately wound in opposite directions and each having a plurality of axially displaced turns. The turns in a layer are insulated from each other by the insulative strip and from turns in adjacent layers by the insulative strip. The entire coil is impregnated with a single resin mass including a filler in the larger coil interstices and in the enveloping resin material where the coil is encapsulated. Due to numerous flow paths provided by the configuration of the flat conductor and the traverse winding, there is solidified resin in even the most remote interstices within the coil, between turns in a layer and between turns in adjacent layers. The very uneven coil end faces provided by the wining layers permit a tight grip of the coil by the resin material enveloping the coil.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view of an encapsulated transformer electrical coil partially in section to show the strip conductor winding and resin encapsulation;

FIG. **2** is a side view of another embodiment of the encapsulated transformer electrical coil, also partially in section;

FIG. **3** is an enlarged cross-sectional view of the resin impregnated and encapsulated electrical coil of FIG. **1**; and

FIG. **4** is an enlarged cross-sectional view of the impregnated and encapsulated electrical coil of FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings in greater detail and in particular to FIG. **1**, an encapsulated transformer coil assembly **2** is shown to include a low voltage winding assembly **10** wound on a transformer core tube **12** and a high voltage winding assembly **14** concentrically wound on the low voltage winding assembly **10**. An insulating barrier **16** separates the low voltage winding assembly **10** and the high voltage winding assembly **14**. The low voltage winding assembly **10** is wound from a

full width foil conductor **18** separated by insulating material **20**. The high voltage winding assembly **14** comprises a continuous, generally flat conductor **22** helically wound to form a plurality of superimposed winding layers such as layers **80** and **82**. Each layer includes a plurality of axially displaced winding turns such as turns **24, 26, 28, 30, 32** and **34** (see FIG. **3**).

In FIG. **3** is shown an enlarged view of the high voltage winding assembly **14** in which adjacent turns such as **30** and **32** of a winding layer are overlapped. It can also be seen in FIG. **3** that the generally flat conductor **22** comprises a continuous conductive strip **48** and a continuous insulative member **50** having a flat face **61** in engagement with the face **52** of the conductive strip **48**. The conductive strip **48** also includes an outer face **58** and the insulative member **50** includes an inner face **60**. In order to facilitate winding of the flat conductor **22** and increase the mechanical strength of the winding assembly **14**, the insulative member **50** may be adhered to the face **52** of the conductive strip **48** in any suitable manner known in the art. The insulative member **50** provides insulation both between adjacent turns in the same winding layer and between adjacent superimposed winding layers. At most operating voltages of the high voltage winding assembly **14**, it may also be necessary to provide creepage distances between edges **54** and **56** of the conductive strip **48** and adjacent turns in the same layer and in adjacent layers. For this purpose the conductive strip **48** is narrower than the insulative member **50** and is spaced from the edges **62** and **64** of the insulative member **50** by the width of margin portions **66** and **68**. It can thus be seen, for example, that the creepage distance between the edges of the conductive strip **48** in turn **26** of layer **80** and the turns **28** and **32** is increased by the width of the margin portion **68**. Where the lengthwise centers of the conductive strip **48** and insulative member **50** are aligned, the width of portions **66** and **68** will be uniform throughout the length of conductor **22**.

The coil assembly **2** is encapsulated and impregnated with a single solidified resinous mass **4** in which a filler material is unevenly distributed. The resinous mass **4** includes an outer enveloping portion **6** which comprises a filled resin, and an impregnating portion **8**. The impregnating portion **8** and outer portion **6** are integral and the portion **8** varies in the amount of filler in the resin. In the smaller interstices within the coil assembly **2**, there is only pure resin since the particles of the filler mixed with the resin are too large to flow into these smaller spaces. The larger interstices of coil assembly **2** contain both resin and filler, the extent of concentration of filler depending on the ability of the filler to flow to and into these larger interstices. The areas in which there will be, or will tend to be, resin and filler or resin alone is indicated by the legends "Filled Resin" and "Resin" in FIGS. **3** and **4** of the drawings. Moreover, the resin portion **8** in the interstices of the coil assembly **2** provides additional insulation and mechanical support of the winding turns. For example, the resin portion **8** in interstices **36** and **38** respectively positioned between turns **24** and **26** and turns **32** and **30** insulates these turns from one another. The resin in the interstices **36** and **38** also insulates layers such as layers **80** and **82** from each other.

Furthermore, the insulative member **50** is relatively flexible so that the margin portions **66** and **68** of the insulative member **50** bend when the resin mass **4** in liquid form is forced into the coil interstices. Because of such flexibility and the spaces created by the difference in width between the conductive strip **48** and insulative member **50**, the margin portions **66** and **68** in engagement with turns of an adjacent layer allow resin to flow into and solidify in the interstice areas such as **70** and **72** to thereby further insulate one winding layer from another.

Also the flexibility of the margin portions **66** and **68** permits impregnation of the coil assembly **2** from one winding layer to another and from one turn to another in the same layer even where the edges **62** and **64** engage each other or some part of the insulative member **50** or conductive strip **48**. In addition, the resin in the various interstices rigidly supports the winding turns and layers so that the coil assembly **2** has excellent mechanical strength.

As previously discussed, the flat conductor **22** is comprised of a continuous conductive strip **48** and insulative member **50**. Use of a continuous flat conductor **22** facilitates winding of the superimposed layers and eliminates the electrical and mechanical stress problems involved when the leads of each coil or layer must be brought out and connected. It should be understood, however, that each layer or several layers may be wound from a separate length of flat conductor and the individual coil leads brought out and connected if desirable. It may be further noted in both FIGS. **1** and **3** that the helical winding of the flat conductor **22** results in an advance of the turns of adjacent layers in opposite directions, so that turns of adjacent layers overlap each other to provide added mechanical strength for the high voltage winding assembly **14**.

With particular reference to FIG. **3**, the reversing of the winding direction of the alternate winding layers such as layers **80** and **82** at the end faces **90** and **92** of the coil assembly **2** produces the uneven surface **94** and **96** at the end faces **90** and **92**. The surface **94** comprises the exposed edges **54** and **62** and exposed flat surfaces **58, 60** and marginal portion **66** of turns such as turn **28** which form the end face **90**. The surface **96** comprises exposed edges **56** and **64**, exposed flat surfaces **58, 60** and **61** marginal partional portion **68** of turns such as turn **34** which form end face **92**.

These exposed edges and flat surfaces thus define spaces such as spaces **98** and **100** respectively extending into the end faces **90** and **92**. The depth of these latter spaces is at least the axial displacement of the turns forming the end faces **90** or **92** plus the width of the margin portions **66** or **68**. This depth will vary somewhat with variations in the winding of the turns at the end faces **90** and **92**. The above described spaces **98** and **100** present a rough surface which the resinous mass **4** can tightly grip to thereby better support the winding layers and minimize separation between the winding assembly **14** and the resinous mass **6**. Moreover, the spaces **98** and **100** provide resin flow paths into the interior of the winding assembly **14** to further assist complete impregnation by the resin.

In an alternative embodiment of the invention illustrated in FIGS. **2** and **4**, elements are referred to by the same reference numerals with the addition of the prime

(') designation. The high voltage winding assembly 14' shown in FIG. 2 includes a generally flat conductor 22' helically wound to form a plurality of superimposed winding layers such as layers 80' and 82' each having a plurality of turns such as turns 26' and 28' in layer 80' and 30' and 32' in layer 82'. The conductor 22' comprises a conductive strip 48' and an insulative member 50'. The conductive strip 48' has edges 54' and 56', a flat face 58' and a flat face 52'. The insulative member 50' has edges 62' and 64', marginal portions 66' and 68' a flat face 60' and a flat face 61' in engagement with face 52' of conductive strip 48'. The conductor 22' of each of the turns such as turns 30' and 32' of layer 82' is displaced axially along the width of the layer 82'. As seen in FIG. 4, the displacement or advance of each turn in each layer of the high voltage winding assembly 14' is at least the full width of the flat conductor 22'. The turns of each layer are thus arranged in juxtaposition with the edges 54' and 56' of the conductive strip 48' of adjacent turns in each layer opposing each other. The advance of each alternate layer is in a direction opposite to that of adjacent layers so that the adjacent turns of adjacent layers overlap each other. In order to provide creepage distances between the conductive strip 48' of adjacent turns in the same layer and in adjacent layers, the conductive strip 48' is spaced from the edges 62' and 64' of the insulative member 50'. Similarly to the embodiment shown in FIGS. 1 and 3, the entire high voltage winding assembly 14' may be formed from a single, elongated strip of flat conductor 22'.

The coil assembly 2' includes a single solidified resinous mass 4' which encapsulates and impregnates the entire coil assembly 2'. The resinous mass 4' has an outer enveloping portion 6' which comprises filled resin and an impregnating portion 8' which is pure resin in the smaller interstices of the coil 2' and filled resin in the larger interstices. The extent of the filler in the resin within the interstices of the coil 2', similarly to the coil assembly 2 of FIG. 3, depends on the size of the interstices and the availability of the path for flow of the resin and filler into the interstices. The resin or resin and filler within interstices such as interstices 74, 76, and 78 insulate adjacent turns in adjacent layers from each other as well as insulate turns in adjacent layers from each other. The resin in interstices such as interstice areas 84 and 86 provide additional insulation between winding layers such as layers 80' and 82'.

Similarly to the embodiment of FIGS. 1 and 3, the crossing of turns in one layer over turns in an adjacent layer provides flow paths for the resin to readily flow into the interior of the coil assembly 2'. The end faces 90' and 92' of the coil assembly 2' also present paths for flow of the resin into the interior of the coil assembly 2' and spaces such as spaces 102 and 104 for tight gripping of the winding by the resin mass 4'.

It can thus be seen that a resin impregnated transformer coil utilizing more economical and manageable narrow conductor strips wound in a traverse configuration has been provided. Conductive strips of the conductor are insulated by insulative strips and resin to provide full insulation and creepage distance between turns in the same layer and turns in adjacent layers. Further, the traverse winding configuration produces a high strength coil and the traverse winding and conductor strip structure together provide resin flow paths resulting in exceptional resin impregnation to further enhance coil strength and insulation. The entire coil structure acts as a filter which permits flow of unfilled resin into smaller interstices while holding filled resin in the larger interstices.

While three specific embodiments of the invention have been shown herein, it will be realized that many modifications thereof are feasible without the from t spirit and scope of the invention. It is consequently intended in the appended claims to cover all such variations and modifications as fall within the true spirit and scope of the invention.

We claim:

1. In an electrical winding assembly, the combination comprising an electrical coil having a continuous conductor including a conductive strip and an insulative strip in facing engagement along their length and being helically wound to form a plurality of superimposed winding layers each having a plurality of axially displaced conductor turns, said coil including a plurality of various size interstices and each two adjacent turns in a layer having a space therebetween, and a resin material comprising a single mixture of a solidified resin and filler, said filler being unevenly distributed in said resin, said resin and filler occupying the larger interstices and spaces of said coil and said resin occupying the smaller interstices and spaces of said coil whereby said turns and layers are insulated from each other and held rigidly in place.

2. In an electrical winding assembly, the combination comprising an electrical coil having a conductor including an insulative strip and conductive strip in facing engagement along their length, said conductive strip being narrower than the insulative strip and being spaced from the edges of said insulative strip, said conductor being helically wound to form a plurality of superimposed winding layers each having a plurality of overlapped conductor turns, the turns of successive adjacent layers being wound in opposite axially advancing directions whereby the turns of adjacent coil layers cross, a plurality of interstices within said coil formed by said winding layers and conductor turns and a resin material comprising a single solidified mixture of a resin and filler, said resin and filler impregnating the larger interstices of said coil and enveloping said coil and said resin impregnating the smaller interstices of said coil.

3. The combination according to claim 1 wherein said resin and filler envelopes said coil.

4. The combination according to claim 3 wherein said coil has two axial end faces, said faces each having an uneven surface comprising a plurality of edges and flat surfaces of said conductor turns, said edges and flat surfaces of said conductor turns, said edges and flat surfaces at each end face defining spaces extending into said end faces a depth not less than the sum of the axial displacement of the conductor turns comprising said uneven surfaces and the distance between the edges of the conductive and insulative strips of a conductor turn, said resin and filler material being tightly gripped within said spaces and being the only electrical insulation on said end faces.

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