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Van Nice

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[54] **INTERLEAVED WINDING FOR ELECTRICAL INDUCTIVE APPARATUS**

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[52] **U.S. Cl.** **336/70;** 336/187
[51] **Int. Cl.**^{2} **H01F 27/28**
[58] **Field of Search** 336/186, 187, 69, 70; 310/213; 174/34

[56] **References Cited**

UNITED STATES PATENTS

3,688,233	8/1972	Moore et al.	336/187 X
3,688,236	8/1972	Boaz et al.	336/187

Primary Examiner—Thomas J. Kozma
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[57] **ABSTRACT**

An interleaved winding constructed of machine transposed conductors. The conductors of the interleaving connections between appropriate conductor locations are fused together by a suitable material to electrically connect all of the strands together, thus eliminating multiple individual strand fusing operations. The fused segments of the interleaving connections are located near the outside of the winding structure.

5 Claims, 3 Drawing Figures

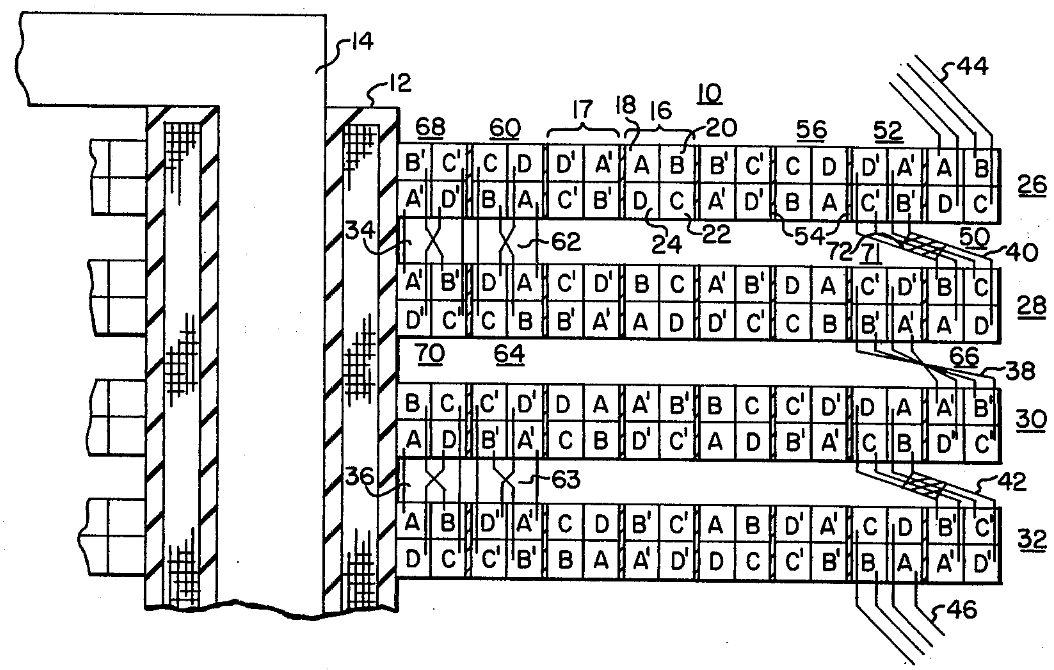


FIG. 1.

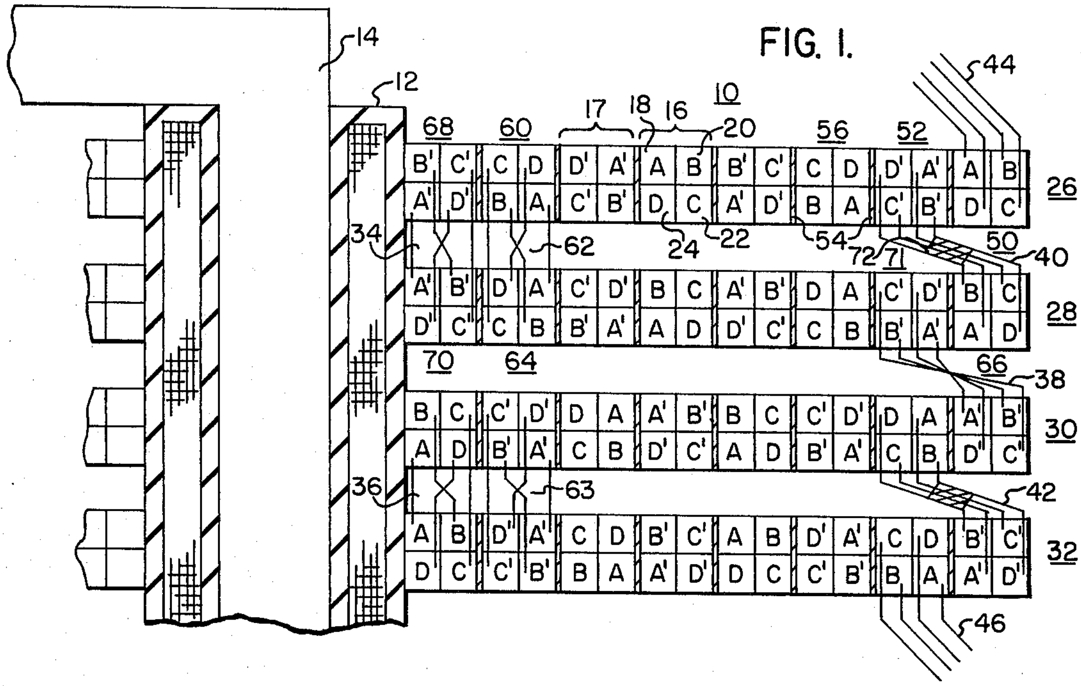


FIG. 2.

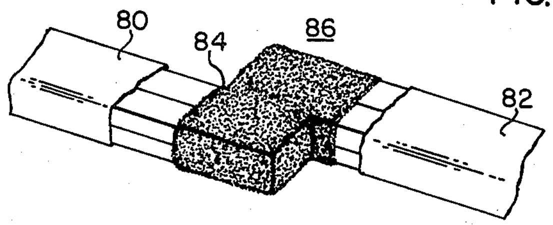
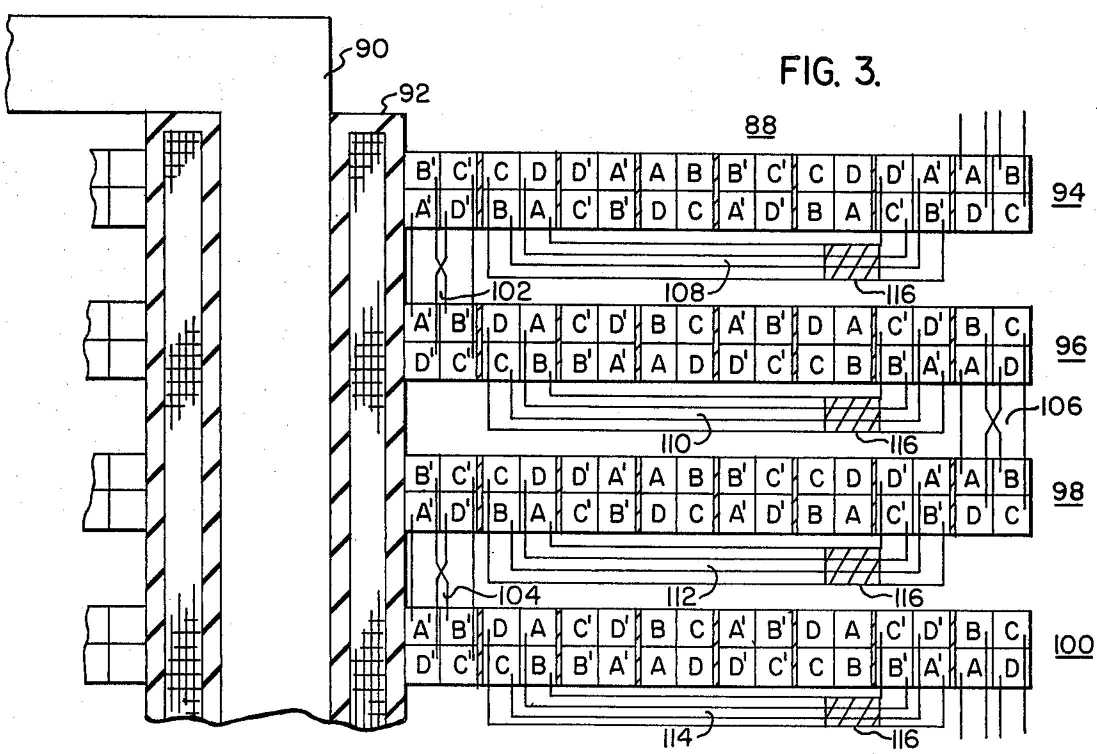


FIG. 3.



INTERLEAVED WINDING FOR ELECTRICAL INDUCTIVE APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates, in general, to electrical inductive apparatus and, more specifically, to interleaved windings for power transformers.

2. Description of the Prior Art

Certain high-voltage, high-current transformer winding structures are difficult to design properly because of conflicting requirements. The high current requirement dictates the use of a stranded conductor to keep eddy currents below reasonable levels. These strands must be transposed throughout the winding to avoid excessive circulating current losses. In addition, the high voltage requirement dictates the use of a winding configuration or arrangement which must withstand lightning surge voltages. Interleaved turn windings are very useful in improving the surge or impulse voltage strength of a winding, but the interleaving pattern and the construction thereof become relatively complicated when more than a few conductors are used. Thus, it has not been feasible in the prior art to obtain the advantages of transposed conductors and conductor interleaving in the same transformer winding structure.

Several arrangements have been tried according to the prior art to obtain the low loss advantages of machine or continuously transposed conductors with a respectable voltage strength. These efforts have increased surge strength by improving the impulse distribution across the winding with shielding arrangements. Such shielding arrangements consist of an extra conductor or wire wound into the disc of the winding. This extra conductor does not carry any load current, but helps carry charging current to smooth out the initial voltage distribution. U.S. Pat. No. 3,691,494 and British Patent No. 1,158,325 describe windings which use such arrangements. Although such arrangements improve the impulse strength of windings constructed of machine transposed conductors, they are disadvantageous from the standpoint of additional material, space and labor necessary to construct the windings.

Therefore, it is desirable, and it is an object of this invention, to provide an arrangement for economically and effectively increasing the impulse strength of transformer windings which are required to carry large currents.

SUMMARY OF THE INVENTION

There are disclosed herein new and useful transformer windings which have high surge voltage strength, low eddy and circulating currents, and reasonable construction costs. Machine transposed conductors are spirally wound around a magnetic core leg, with the turns of the conductors being interleaved with each other. The interleaving connections electrically connect together the interleaved conductors and include a segment in which all of the strands of the machine transposed conductor are fused together. By joining the conductors together in this manner, the use of machine transposed conductors in interleaved turn windings is economically feasible. Circulating current flow through the conductor strands is reduced by the occupancy of each conductor strand position of the conductor due to the continuous transposing.

BRIEF DESCRIPTION OF THE DRAWING

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

FIG. 1 is a schematic illustration of a twin interleaved winding structure constructed according to this invention;

FIG. 2 is a view illustrating an arrangement for making the interleaving connections between the coil discs of the winding structure; and

FIG. 3 is a schematic illustration of a single interleaved winding structure constructed according to this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Throughout the following description, similar reference characters refer to similar elements or members in all of the Figures of the drawing.

Referring now to the drawing, and to FIG. 1 in particular, there is shown a schematic illustration of a twin interleaved winding contructed according to this invention. The interleaved winding **10** in this embodiment is a high-voltage winding which is disposed around the low-voltage winding **12** and the magnetic core leg **14.** The portion of the transformer shown in FIG. 1 may be a part of a single-phase or a multiple-phase transformer without departing from the scope of the invention.

The winding **10** is constructed of machine transposed conductors, such as the conductor **16** which comprises the conductor strands **18, 20, 22** and **24.** The winding development and general construction techniques of the winding shown in FIG. 1 are described in more detail in U.S. Pat. No. 3,477,052, which is assigned to the assignee of this invention. Among other differences, the winding **10** taught by the present invention uses machine transposed conductors in place of the non-transposed conductors taught by U.S. Pat. No. 3,477,052.

A machine transposed conductor is a conductor which consists of several strands which are insulated electrically from each other throughout the length of the conductor. The transpositions are placed into the conductor before it is wound into the winding structure. At regular intervals along the length of the conductor, crossovers or transpositions of the conductor strands occur and the relative position of the conductor strands are changed. After a sufficient number of transpositions, each strand in the conductor occupies every strand location in the conductor, thus reducing any effects of unequal flux linkage at different radial positions in the conductor. Machine transposed conductors suitable for use with power transformer windings are commercially available and have a strand transposition at approximately every three inches of conductor length.

The high-voltage winding **10** shown in FIG. 1 includes the coil discs **26, 28, 30** and **32.** The coil discs are interconnected by the start-start connections **34, 36, 62** and **63,** the finish-finish connection **38,** and the interleaving connections **40** and **42.** The leads **44** and **46** extending from the winding **10** may be used to connect the winding to associated electrical apparatus or to other windings or winding discs associated with the four coil discs shown in FIG. **1.** It is emphasized that the invention disclosed herein is not limited to a winding structure having exactly four coil discs as shown in FIG. 1.

The interleaving connections are characterized by the necessity of splicing or connecting the conductors from adjacent discs to each other to form the interleaving connection. This is in contrast to the finish-finish connection **38** which is formed by an extension of the conductor from the disc **28** to the disc **30** during the winding process. No splicing or connecting operation is required to provide the finish-finish connection **38,** thus the individual strands which comprise the finish-finish connection **38** remain individually insulated from each other.

As described in more detail in U.S. Pat. No. 3,477,052 each coil disc of the winding **10** is wound by simultaneously winding two conductors at the same time spirally around a suitable winding mandrel. At appropriate intervals during the winding operation, the condutors are cut and appropriately spliced together to provide the interleaved turn winding development which is desired. In each coil disc, adjacent conductors are supplied by different conductor spools. For example, in the coil disc **26,** the conductor **16** is supplied by a different conductor spool than the conductor **17.**

The insulation between the conductor strands is not illustrated in FIG. **1** in the interest of clarity. However, the insulating material **54** is illustrated between the conductors to indicate the number of strands included in each conductor. Although only two separate conductors are used to construct the winding **10,** it is convenient to refer to the various positions of the conductors as "conductor locations."

The conductor location **50** includes the strands which are designated with the letters A, B, C and D. The conductor location **52** includes the strands which are designated by the letters A′, B′, C′ and D′. The progression of these strands in the coil discs may be determined by following the relative placement of the strand letters within the different conductor locations. For example, at conductor location **56,** the strands have effectively rotated clockwise two strand positions from the outermost conductor location **50** which is one winding turn distant. This indicates that there has been two strand transpositions between the two conductor locations, however, this is only illustrative of the physical changes produced by the transpositions and a different number of transpositions could have actually occurred in the one winding turn therebetween. For example, six winding transpositons could have occurred between the conductor location **50** and the conductor location **56.** In addition, the number of strands for each conductor is not limited to four as shown in FIG. **1.** A different number of strands, including an odd number of strands, may be used without departing from the spirit of the invention. Four strands are shown for convenience only.

The machine transposed conductors are interconnected and wound in a manner which provides a conduction path which begins at the outer conductor location **50** and progresses inwardly to the conductor location **60,** across the start-start connection **62** to the conductor location **64,** and then outwardly to the conductor location **66.** At this point, the conduction path traverses the interleaving connection **40** to the conductor location **52** and progresses inwardly to the conductor location **68.** The conduction path then traverses the start-start connection **34** to the conductor location **70,** then outwardly to the conductor location **71.**

The interleaving connection **40** provides the electrical connection between the two conductors which are used to construct the winding **10.** Rather than connect each strand individually to each other in the interleaving connection **40,** the group of strands in each conductor are fused together at the segment **72** in the interleaving connection **40** to electrially connect all of the strands in each conductor together. Such a fusion technique provides a simple method for connecting the multiple strand conductors together and permits the economical use of machine transposed conductors in interleaved turn windings. Circulating currents through the separate strands are not troublesome because of the plurality of complete transpositions of the conductor between the fused segments of the interleaving connections. In addition, the stranded conductor tranverses four separate coil discs between each fused segment of an interleaving connection, thus the length of the strand between the fused segments is sufficiently long enough to reduce circulating currents. Eddy currents in the fused segment itself are relatively small due to the location of the fused segment **72** near the outside of the winding **10** which is away from the leakage flux area normally located in the region between the windings **10** and **12.**

FIG. **2** is a view of two stranded conductors which are fused together in a manner which may be used to provide the fused interleaving connections shown in FIG. **1.** The conductors **80** and **82** are fused together by the fusion material **84** which may consist of a suitable heat melting material, such as a solder or brazing alloy. Normally, any insulating coating on the strands of the conductors **80** and **82** would be removed before the fusion material **84** is applied. Although the conductors **80** and **82** are shown in FIG. **2** as being positioned adjacent to each other, there are other overlapping and interwoven arrangements which may be used within the scope of this invention. The fused segment **86** would normally be insulated by a suitable wrapping of insulating material therearound.

FIG. **3** is a view illustrating the invention as applied to a single-interleaved turn winding, such as that described in U.S. Pat. No. 3,090,022. The winding **88** is disposed around the winding **92** and the magnetic core leg **90.** The winding development of this winding is characterized by the fact that the conduction path traverses each coil disc twice in the smae direction before traversing a connection to the next coil disc. The winding **88** includes the coil discs **94, 96, 98** and **100.** Interconnection between the coil discs is provided by the start-start connections **102** and **104,** and by the finish-finish connection **106.** The interleaving connections illustrated in FIG. **3** include the interleaving connections **108, 110, 112** and **114.** The interleaving connections are fused together at the segments **116** which include a fusion material as discussed in connection with FIG. **1** and **2.** Thus, all of the strands of each conductor which form the interleaving connections are individually electrically connected to each other within the segment **116.** The fused segment **116** is positioned toward the outer radial surface of the winding **88** to reduce the losses therein occasioned by the leakage flux field which is stronger toward the innermost radial surface of the winding **88.**

Although the invention has been disclosed and described herein in connection with two specific interleaved turn winding arrangements, it is emphasized that the arrangement disclosed herein may be used with any type of interleaved turn winding which may be wound with machine transposed conductors. The arrangement disclosed herein permits the winding and efficiency advantages of the machine transposed conductor together with a practical and efficient arrangement for making connections between the separate stranded conductors.

Since numerous changes may be made in the above described apparatus, and since 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 drawing, shall be interpreted as illustrative rather than limiting.

I claim as my invention:

1. An interleaved winding for power transformers, comprising:

at least one coil disc which contains a continuously transposed conductor having a plurality of conductor strands which are spirally disposed around the winding axis for a plurality of turns to form a plurality of stranded conductor locations, with each turn containing a plurality of strand transpositions; and

an interleaving connection which connects together two stranded conductor locations in said winding, and which electrically connects all of the strands in the interleaving connection to each other.

2. The interleaved winding of claim 1 wherein the two stranded conductor locations are in the same coil disc.

3. The interleaved winding of claim 1 wherein the two stranded conductor locations are in different coil discs.

4. The interleaved winding of claim 1 wherein the interleaving connection includes a section in which all of the strands in the connection are fused together by an electrically conductive material.

5. The interleaved winding of claim 4 wherein the fused section is located near the outer radial portion of the winding.

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