United States Patent

Millsop et al.

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[54] MAGNETIC CORES AND METHODS OF CONSTRUCTING SAME

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[21] Appl. No.: 143,429

[52] U.S. Cl. 336/217, 29/609

[51] Int. Cl. H01f 27/04, H01f 41/02

[58] Field of Search 336/212, 216, 217; 29/609, 29/607

[56] References Cited

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2,929,038 3/1960 Sonesson ....336/217 X

3,540,120 11/1970 De Laurentis et al....................336/217 X

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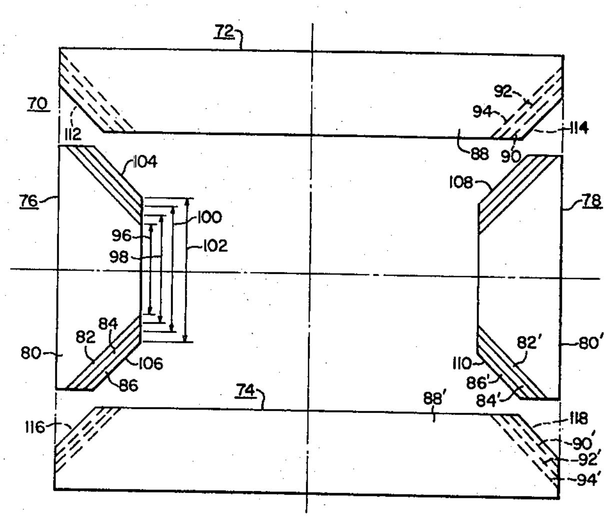
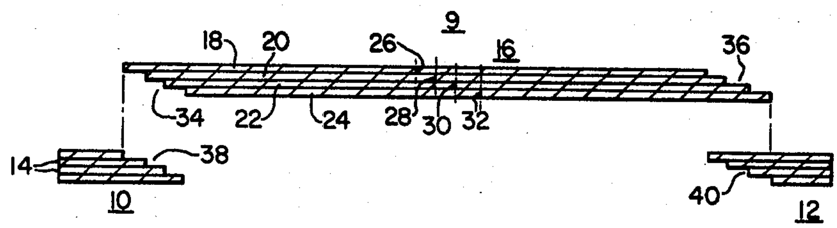
[57] ABSTRACT

Magnetic cores of the stacked type, and methods of constructing same, having stepped-lap joints between adjoining leg and yoke portions of the core. The length dimensions of the leg and yoke laminations are changed in opposite directions from layer to layer of the magnetic core, while maintaining the midpoints of the laminations in each leg and yoke position in alignment. This arrangement offsets the ends of the laminations from one another, at each end of each leg and yoke portion, in a predetermined stepped pattern, with the stepped patterns of adjoining leg and yoke portions being complementary to provide the desired stepped-lap joints.

17 Claims, 13 Drawing Figures





PRIOR ART

FIG. 1.

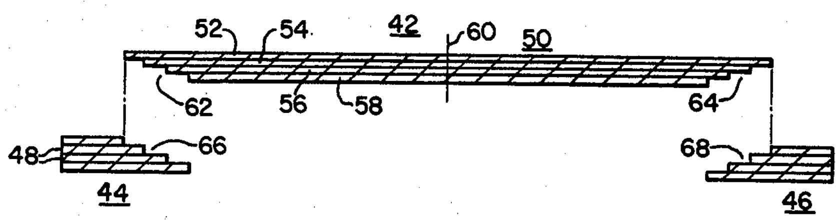


FIG. 2.

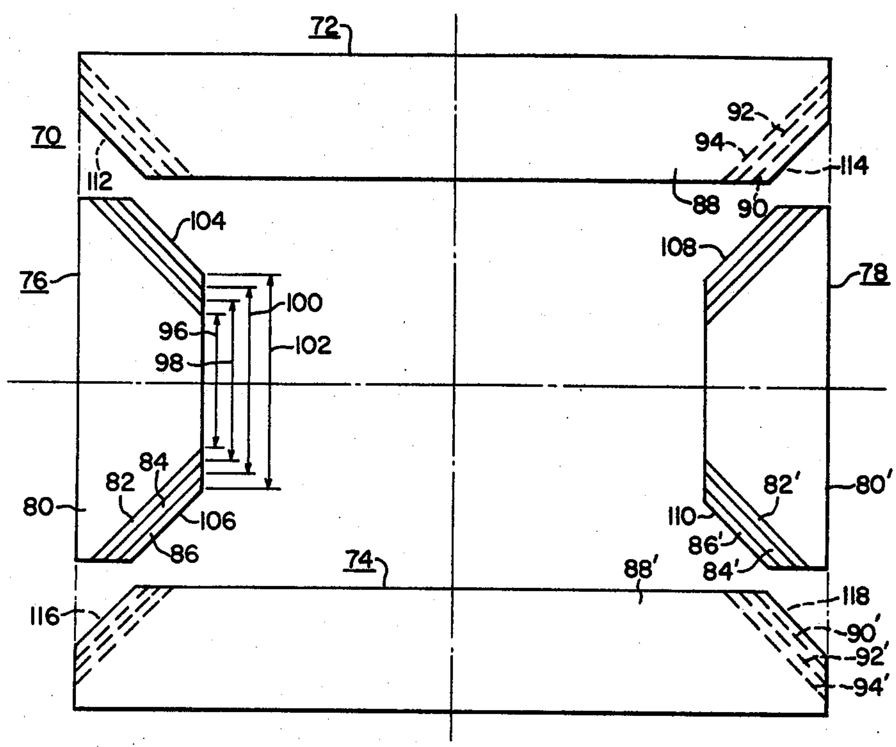


FIG. 3.

WITNESSES

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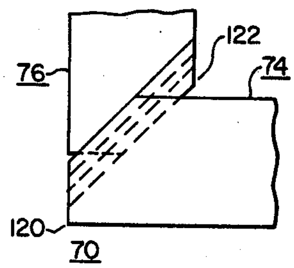

FIG.3A.

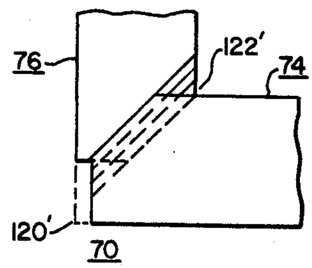

FIG.3B.

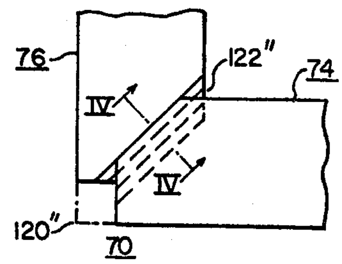

FIG.3C.

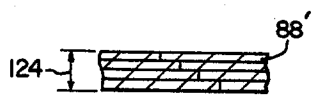

FIG.4A.

FIG.4B.

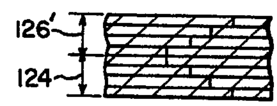

FIG.4C.

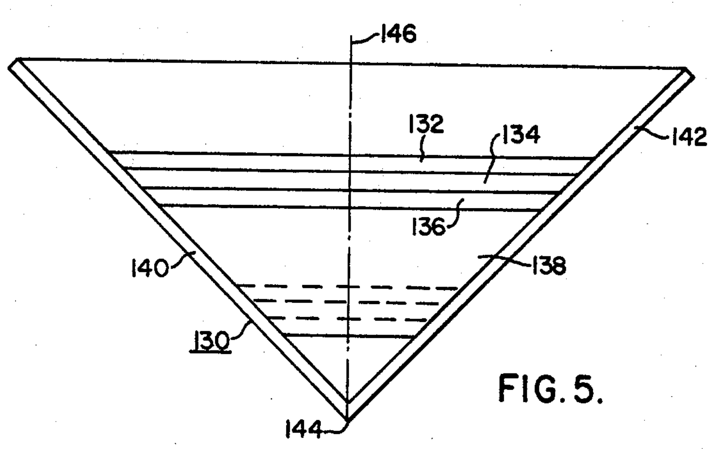

FIG.5.

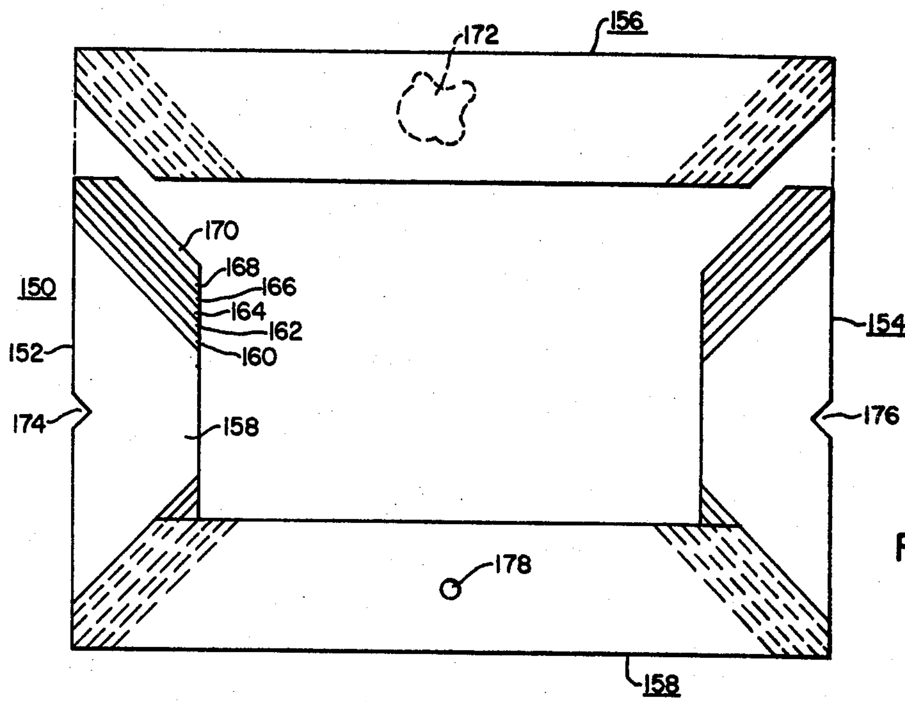

FIG. 6.

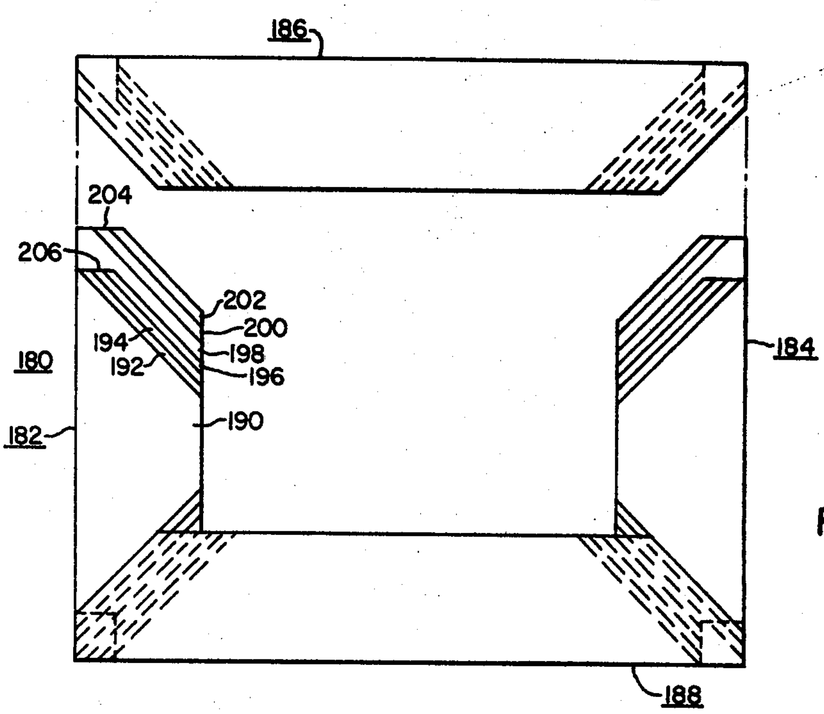

FIG. 7.

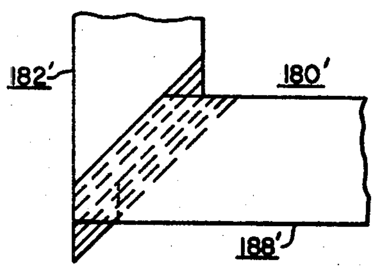

FIG. 7A.

MAGNETIC CORES AND METHODS OF CONSTRUCTING SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to magnetic cores, and more specifically to magnetic cores of the stacked type for electrical inductive apparatus, such as transformers and electrical reactors, having stepped-lap joints between adjoining leg and yoke portions of the core.

2. Description of the Prior Art

U.S. Pat. Nos. 3,153,215, 3,210,709, 3,477,053 and 3,540,120, which are assigned to the same assignee as the present application, all disclose magnetic core structures of the stacked type having stepped-lap joints between adjoining leg and yoke portions of the core. A stepped-lap joint is defined as the type of joint wherein the joints between adjoining leg and yoke laminations are incrementally offset from similarly located joints, from layer to layer through the stacked core in a predetermined stepped pattern, with the joints of the pattern progressing for at least three steps in a given direction before the pattern is repeated or the stepping direction changed. The stepped-lap joint construction was found to improve the performance of a magnetic core, compared with the butt-lap type joint, such as disclosed in U.S. Pat. No. 2,300,964, which patent is also assigned to the same assignee as the present application. The stepped-lap construction reduces the core losses (T.W.), the exciting-volt amperes (A.W.) and noise level, compared with magnetic cores constructed with joints according to the teachings of the prior art, and it facilitates the construction of the magnetic core as the laminations may be handled and assembled in groups of laminations.

In general, the prior art stepped-lap joint arrangements, as disclosed in the hereinbefore mentioned patents, obtain the desired stepped relationship between diagonally cut ends of the laminations by providing laminations for each leg or yoke portion which have the same longitudinal dimension between the diagonally cut ends. The stepped relationship is achieved by incrementally offsetting the midpoints of the laminations of any stacked group of laminations, providing a stepped relationship between the ends of the laminations, on each end of the group, but the steps appear on opposite sides of the group. Thus, in assembling a group of incrementally offset laminations, with two other groups of laminations, such as assembling a group of yoke laminations with two spaced groups of leg laminations, it is necessary to tuck one end of the group of yoke laminations under the ends of one of the groups of leg laminations. This "blind" assembly of stepped ends increases the assembly time of the magnetic core, it may necessitate flexing or bending of the group of laminations in order to tuck the ends of the yoke laminations under the ends of the leg laminations, which may create stresses in the laminations and adversely affect the magnetic quality of the laminations, and a frictional drag is created between the yoke laminations being tucked under the ends of the leg laminations, which may cause an undesirable shifting of previously placed laminations.

Thus, it would be desirable to provide a new and improved magnetic core structure, and methods of constructing same, having stepped-lap joints between adjoining leg and yoke portions of the magnetic core, which does not require "blind" assembly of any of the stepped-lap joint structures.

SUMMARY OF THE INVENTION

Briefly, the present invention is a new and improved magnetic core structure, and methods of constructing same, which creates stepped-lap joints by changing the length of the laminations, between their diagonally cut ends, from layer to layer of the magnetic core, with the dimensions of the yoke and leg laminations changing in opposite directions from layer to layer. The midpoints of the laminations of each yoke and leg portion are aligned. In a predetermined stepped-lap pattern, if the leg laminations are increasing in length from layer to layer, the corresponding yoke laminations will decrease in length, and vice versa. This arrangement places the stepped ends of any group of laminations on the same side of the group. Thus, the leg portions of the magnetic core may be constructed in groups of laminations in which the stepped ends on both ends of the groups face upwardly, outwardly, or otherwise towards the assembler. The stepped ends of the groups of adjoining yoke laminations then may be placed directly over the stepped ends of the groups of leg laminations, without any tucking under of laminations required.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be better understood and further advantages and uses thereof more readily apparent, when considered in view of the following detailed description of exemplary embodiments, taken with the accompanying drawings, in which:

FIG. 1 is a view, in section, which illustrates the prior art arrangement of constructing stepped-lap joints between adjoining leg and yoke portions of the magnetic core;

FIG. 2 is a view, in section, which illustrates the construction of stepped-lap joints between adjoining leg and yoke portions of the magnetic core, according to the teachings of the invention;

FIG. 3 is a plan view which illustrates the assembly of a magnetic core according to the teachings of the invention;

FIGS. 3A, 3B and 3C illustrate three different joint arrangements which may be used with the magnetic core shown in FIG. 3;

FIGS. 4A, 4B and 4C are cross sectional views of the stepped-lap joint arrangement shown in FIG. 3C, taken in the direction of arrows IV—IV, illustrating a single group of adjoining leg and yoke laminations, two superposed groups oriented in a similar manner, and two superposed groups oppositely oriented, respectively;

FIG. 5 is a plan view illustrating a method of orienting the midpoints of a group of laminations having different length dimensions between their diagonally cut ends;

FIG. 6 is a plan view of a magnetic core constructed according to another embodiment of the invention, and illustrating different ways of orienting the laminations to provide the stepped joint construction;

FIG. 7 is a plan view of a magnetic core constructed according to still another embodiment of the invention; and

FIG. 7A is a fragmentary view which illustrates an alternate embodiment of the magnetic core structure shown in FIG. 7.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and FIG. 1 in particular, there is shown a cross sectional view of a typical prior art arrangement **9** for constructing stepped-lap joints. Groups **10** and **12** of laminations, such as laminations **14** in group **10**, represent two spaced leg portions of a magnetic core, and group **16** of laminations represents a yoke portion which is to interconnect the ends of groups **10** and **12**. Group **16** includes laminations **18**, **20**, **22** and **24** which are like dimensioned between their diagonally cut or mitered ends, with the stepped relationship between the diagonally cut ends being established by incrementally shifting the centerlines of midpoints **26**, **28**, **30** and **32** of laminations **18**, **20**, **22** and **24**, respectively. This incremental shifting of lamination midpoints steps the diagonally cut ends of the laminations, at both ends of the group **16**, providing a stepped relationship **34** on one side of group **16**, and a stepped relationship **36** on the other side of the group. The stepped end **34** of group **16** may be easily assembled with stepped end **38** of group **10**, as it may simply be placed in position, but the assembly of stepped end **36** of group **16** with stepped end **40** of group **12** is more difficult, as stepped end **36** will have to be tucked under the outwardly extending ends of stepped end **40** in order to butt the diagonally cut ends of the laminations of group **16** with those of group **12**.

If the magnetic core shown in FIG. 1 is of the shell-form type, the view in FIG. 1 will be an elevation, as the laminations are normally stacked with their major planes horizontal, necessitating bending or flexing of group 16 in order to assemble the groups, or sliding the laminations in from the side. The larger overlaps between joints on the large shell-form magnetic cores, which are required to increase the short circuit mechanical strength of the magnetic core, such as one-fourth to three-eighths inch, makes the stacking problem even more difficult. If the magnetic core shown in FIG. 1 is of the core-form type, FIG. 1 would be a top or plan view, and group 16 would have to be flexed, or the laminations of group 16 would have to be placed in the same planes as the laminations of groups 10 and 12, and advanced into the position from the top or bottom of the core, depending upon whether group 16 is from the top or bottom yoke portions of the core. If it is from the bottom yoke portion, the holding fixture will preclude sliding the group of laminations in from the bottom, and if it is the top yoke, it would be awkward to handle the laminations and slide them in from the top, especially on the larger core-form type magnetic cores.

FIG. 2 is a cross sectional view of a new and improved arrangement 42 for constructing magnetic cores, which arrangement eliminates the disadvantages of the prior art arrangement shown in FIG. 1. Groups 44 and 46 of laminations, such as laminations 48 in group 44, represent two spaced leg portions of a magnetic core, and group 50 of laminations 52, 54, 56 and 58 represent a yoke portion which is to interconnect the ends of groups 44 and 46.

Laminations 52, 54, 56 and 58 of group 50, instead of having like dimensions between their diagonally cut ends, and incrementally offset midpoints, such as taught by the prior art, have different or varying lengths between their diagonally cut ends from layer to layer, and the midpoints of the laminations are aligned in each portion of the magnetic core, such as indicated by center line 60. Further, the laminations of each group are arranged according to length, with the longest lamination being on one side of the group and the shortest on the other side. For example, group 50 starts with its longest lamination 52 on one side of the group and progresses through the laminations according to length, with the shortest lamination 58 being on the opposite side of the group, providing progressively stepped arrangements 62 and 64 at opposite ends of group 50, with both arrangements being located on the same side of the group. Groups 44 and 46 are constructed similar to group 50, but oriented with their stepped ends facing the stepped ends of group 50, with group 44 having a stepped end 66 which is complementary to stepped end 62 of group 50, and group 46 having a stepped end 68 which is complementary to stepped end 64 of group 50. Thus, group 50 may be easily assembled with groups 44 and 46 by merely placing group 50 in the desired position over the ends of groups 44 and 46. The assembly shown in FIG. 2 may be constructed without tucking any laminations under other laminations. Flexing or bending of laminations is eliminated. The assembly is not "blind", and there is no frictional drag on previously placed laminations which would force these laminations out of position.

FIG. 3 illustrates a magnetic core 70, which is in the process of being constructed according to a first embodiment of the invention. If the magnetic core 70 shown in FIG. 3 is of the shell-form type, the view shown would be a plan view, and if it is of the core-form type, it would be an elevational view. It is to be understood that the magnetic cores shown in the drawings, and the methods disclosed for constructing them, may be either shell-form, or core-form.

Magnetic core 70 includes first and second portions 72 and 74, which may be leg or yoke portions, depending upon the specific construction of the magnetic core and its intended use, and first and second portions 76 and 78, which may also be leg or yoke portions. Each portion of magnetic core 70 includes a stack of superposed, metallic laminations, with each stack of laminations being made up of one or more groups of laminations. For purposes of example, it will be assumed that each group of laminations includes four laminations, but in practice more laminations will usually be used in each group. The number of laminations in a group depends upon the number of steps desired in the stepped-lap joint between adjoining leg and yoke portions of the core.

More specifically, portion 76 has first, second, third and fourth laminations 80, 82, 84 and 86, portion 78 has similarly shaped and dimensioned laminations, since it is similar to portion 76 in function. Like reference numerals are used to indicate like dimensioned laminations in portions 76 and 78, with a prime mark added to the reference numerals of portion 78. Portion 72 of magnetic core 70 has first, second, third and fourth laminations 88, 90, 92 and 94, and portion 74, which is similar in function to portion 72, has laminations with the same reference numerals as those in portion 72, with the addition of a prime mark.

The step of providing the laminations for magnetic core 70 may be performed by cutting the laminations from a strip of magnetic, metallic material, such as grain oriented silicon steel, using a shear which cuts the strip diagonally at predetermined locations to provide laminations have a substantially trapezoidal configuration, with the diagonally cut ends forming the non-parallel sides of the trapezoid, and the edges of the strip forming the parallel sides of the trapezoid. Instead of cutting all of the leg laminations to the same configuration and dimensions, and instead of cutting all of the yoke laminations to the same configuration and dimensions, the lengths of the punchings or laminations for both the leg and yoke portions are varied. The shear used to cut the strip diagonally may be programmed to vary the lengths of the laminations as required by the specific stepped-lap pattern construction desired.

The different length laminations for each portion of magnetic core 70 is illustrated relative to portion 76, with lamination 80 having a length dimension 96 between its diagonally cut ends. The dimension between diagonal ends is defined as that dimension between the ends located on the shortest side of the two parallel sides of the trapezoidal configuration, as the dimension of the longest side may be altered after the lamination is cut, such as by incrementally cutting the lamination tips in order to more easily obtain the stepped relationship between a group of laminations. The length dimension 96 of lamination 80 is the shortest of the group, with lamination 82 having a dimension 98 which is longer than dimension 96. The difference in the lengths of laminations 80 and 82 is determined by the amount of overlap desired in the stepped-lap joint structure to be formed between adjoining yoke and leg portions of the core. In like manner, lamination 84 has a dimension 100 which is longer than dimension 98, and lamination 86 has a dimension 102 which is longer than dimension 100. The remaining portions 72, 74 and 78 have the lengths of their respective laminations varied similar to portion 76.

After providing the laminations for the yoke and leg portions of the magnetic core 70, the laminations for each leg and yoke portion are stacked in superposed groups, with the laminations in each group being sequenced according to length. In other words, the shortest lamination is on one side of each group and the longest lamination is on the other side, with the laminations between these two laminations increasing in length from the shortest to the longest lamination. Further, instead of offsetting the midpoints or centerlines of the laminations, which midpoint or centerline divides the lamination length into two equal portions, the midpoints or centerlines of the laminations in each group are all aligned with one another, which therefore spaces the diagonally cut ends of the laminations from one another at each end of the group, with the progressive steps of the resulting stepped structure appearing on the same side of each group. Thus, portion 76 has stepped arrangements 104 and 106 at its ends, portion 78 has stepped arrangements 108 and 110 at its ends, portion 72 has stepped arrangements 112 and 114 at its ends, and portion 74 has stepped arrangements 116 and 118 at its ends.

The stepped arrangement at each end of each group may be easily achieved by incrementally clippinG at least one end of each lamination of each group, on the same end of the group, and aligning the clipped ends, such as by placing them against a plane surface while maintaining the parallel edges of the group of laminations in alignment. The groups shown in FIG. 3 have both ends of their respective laminations incrementally clipped, but for establishing the desired stepped relationship between the diagonal ends of the laminations, it is necessary to clip only one end. The clips on the other end will prevent the points on this end of the group from protruding past the major sides of the magnetic core when certain types of corner joints are utilized. If the protruding ends will not cause interference in the intended assembly, they may be left unclipped. For example, in core-form construction, protruding ends may interfere with end frames, while in shell-form construction protruding ends may interfere with form-fit type tanks.

In the assembly of portions **72**, **74**, **76** and **78**, two of the parallel disposed portions, such as portions **76** and **78**, are placed such that their stepped arrangements **104**, **106**, **108** and **110** face the assembler. In a shell-form core the magnetic core is built up around the windings, and it would not be important as to whether the steps on portions **76** and **78** face the assembler, or the steps on portions **72** and **74**. With a core-form core, the leg portions should be constructed such that their steps face the assembler, as it will facilitate the assembly of the top and bottom yokes.

After the groups which form portions **76** and **78** are positioned in spaced, parallel relation, the groups which form portions **72** and **74** may be placed into position, without flexing or bending the groups, with the steps of portions **72** and **74** facing away from the assembler to provide complementary steps between the leg and yoke portions of the core. The stepped arrangements of the leg and yoke portions fit together to provide diagonal stepped-lap joints, with the diagonally cut edges of each layer of laminations abutting together. It will be noted from FIG. 3 that starting with the uppermost layer of laminations, and progressing downwardly through the layers, that the lengths of the leg and yoke laminations vary in opposite directions, i.e., the laminations in portions **72** and **74** decrease in length between their diagonally cut ends, while the laminations of portions **76** and **78** increase in length between their diagonally cut ends.

When the yoke and leg portions of magnetic core **70** are assembled, the adjoining leg and yoke portions may be placed relative to one another as shown in the fragmentary view of magnetic core **70** in FIG. 3A, which places the geometrical outer corner of the magnetic core **70** at the point **120**, which is a corner of the portion **74**. However, it will be noted that this arrangement of portions **74** and **76** generates a substantial void volume at the associated inner corner **122**. Since the overlap dimension is necessarily shown large, relative to the other dimensions of the laminations in the Figures, in order to adequately illustrate the stepped-lap construction, the void volume is magnified out of proportion in the drawings, compared with actual construction, but it does illustrate that the flux will be forced outwardly adjacent to the inner corner **122**, increasing the length of the mean flux path, causing flux crowding and higher losses. As shown in FIG. 3B, portions **74** and **76** may be moved relative to one another along the diagonal joints between them, in a manner as disclosed in the hereinbefore mentioned U.S. Pat. No. 3,477,053, to provide an inner corner **122'** which has less void volume, and an outer corner **120'** which has more void volume, and the geometrical location of the outer corner **120'** has been moved between portions **74** and **76**. The transfer of a portion of the void volume to the outer corner is beneficial, as the normal tendency of the magnetic flux is to hug the inner corner, with the outer corners of the core having a relatively low flux density. FIG. 3C, illustrates a still greater relative movement between portions **74** and **76** along their diagonal joints, to balance the void volume between the inner and outer corners **122''** and **120''** respectively, and to also balance the void volume at the inner corner **122''** between the two adjoining portions **74** and **76** of the magnetic core. The geometrical outer corner **120''** is also balanced between the portions **74** and **76**, placing half of the corner joints on one side of corner **120''** and half of the joints on the other side of the corner.

FIG. 4A is a cross sectional view of the stepped-lap joint shown in FIG. 3C, taken in the direction of arrows IV—IV. The stepped-lap joint shown in FIG. 4A is constructed of a single group of leg laminations and a single group of yoke laminations, with this first assembly of groups being referenced **124**. The next assembly of groups of leg and yoke laminations, which is referenced **126**, may be constructed and oriented in the same manner as the first assembly **124**, which will repeat the stepped-lap pattern of the first assembly **124**. This arrangement is shown in FIG. 4B. Or, the second assembly **126** may be turned over, relative to the position of the first assembly **124**, such as shown at **126'** in FIG. 4C, and this arrangement reverses the stepping pattern of the first assembly.

In certain stepped-lap joint arrangements, the number of laminations in a basic stepped-lap pattern, and the dimensions of the overlap, may not make it practical to incrementally clip all of the ends of the laminations at one end of a group of laminations, and align these clipped ends against a common plane. FIG. 5 is a plan view of a simple fixture **130** which may be used to quickly align the laminations **132**, **134**, **136** and **138** of a group of laminations, taking advantage of the symmetrical stacking of the varying length laminations, wherein their centerlines or midpoints are aligned. Fixture **130** includes first and second wall portions **140** and **142**, the ends of which are joined at corner **144**, with the angle between the two wall portions being 90°. The various laminations, after they are cut on a programmed shear, may be automatically directed to the proper fixtures for the leg and yoke portions. The laminations will be automatically centered in this right angle fixture, aligning the midpoints or centerlines of the laminations disposed therein along the centerline **146**.

Figure 6 illustrates a magnetic core **150** with a stepped-lap joint construction having 7 layers of laminations in the basic pattern, which illustrates that a portion of the laminations of a basic group may be incrementally clipped, and a portion of the laminations unclipped. Magnetic core **150** includes first and second spaced parallel portions **152** and **154**, which may be leg or yoke portions, depending upon the type of apparatus the magnetic core is to be used with, and first and second portions **156** and **158** which join the ends of portions **152** and **154** to provide a substantially rectangular structure defining a closed magnetic circuit which has four outer corners and associated inner corners. Each portion includes seven laminations, such as laminations **158**, **160**, **162**, **164**, **166**, **168** and **170** of portion **152**. These laminations vary in length, and are stacked according to length with their midpoints aligned. Laminations **166**, **168** and **170** are incrementally clipped, and laminations **158**, **160**, **162** and **164** are unclipped. Since the laminations of the basic groups cannot all be assembled and their stepped relationship developed by aligning incrementally clipped ends, the incremental clips are shown merely to prevent their ends from extending beyond the edges of the magnetic core, and these ends may be left unclipped if they will not cause interference in the assembly of the magnetic core.

FIG. 6 illustrates different ways of developing the desired stepped arrangement in each group. For example, portion **156** may have a room temperature curable adhesive **172** applied to each lamination as it is being directed into fixture **130** shown in FIG. 5. Alignment of the parallel edges of the laminations as they are removed from the fixture and allowing the adhesive to cure, will enable the laminations to be handled as a coherent group. The adhesive may also be applied to the edges of the laminations after the group is properly assembled, as disclosed in the hereinbefore mentioned U.S. Pat. No. 3,210,709.

Portions **152** and **154** have recesses or notches **174** and **176**, respectively, formed in an edge of each lamination of their respective groups, which, when aligned, will provide the required stepped relationship between the ends of the laminations, and portion **158** has an opening or recess **178** disposed completely through each lamination intermediate its parallel edges, which when aligned provides the required stepped relationship at each end of the group. Notches and circular openings in the laminations are disclosed in the hereinbefore mentioned U.S. Pat. No. 3,153,215. It will be noted that stepped-lap joints between the leg and yoke portions of magnetic core **150** appear on both sides of the geometrical outer corners of the magnetic core, and that the relative locations of the adjoining leg and yoke portions, along their diagonal joints, have been selected to balance the void volume at the inner corners between the leg and yoke portions of the core.

FIG. **7** illustrates a magnetic core **180**, similar to magnetic core **150** shown in FIG. **6**, except modified to illustrate an embodiment of the invention wherein all of the laminations are incrementally clipped, with one-half of the laminations in each group of laminations having their incrementally clipped ends aligned, and the other half of the laminations in each group having their incrementally clipped ends aligned, with the ends of the two groups being spaced from one another. More specifically, magnetic core **180** includes first and second parallel portions **182** and **184** which may be leg or yoke portions, and first and second portions **186** and **188** which join the ends of portions **182** and **184**, to provide a substantially rectangular structure having four outer corners and associated inner corners, which defines a closed magnetic loop for use in shell-form inductive apparatus, or core-form apparatus, as desired. Each basic group of laminations in each portion of the magnetic core **180** have seven laminations, with portion **182** having laminations **190, 192, 194, 196, 198, 200** and **202**. The laminations of portion **182** have different lengths between their diagonally cut end portions, and they are stacked according to length with their midpoints aligned, providing a stepped relationship on each end of the group, and on the same side of the group. The longer laminations **198, 200** and **202** have their ends incrementally clipped and aligned in a common plane **204**, and the shorter laminations **190, 192, 194** and **196** have their ends incrementally clipped and aligned along a plane **206**, with the lines or planes **204** and **206** being offset or spaced from one another. This arrangement enables each group to be initially handled as two separate groups, aligning each portion of the group with its clipped ends against a plane surface to develop the desired stepped relationship, and the other half of the group having its clipped ends aligned to establish the desired stepped relationship between its laminations. The two halves of the group may then be placed together, with their midpoints aligned, to provide a complete group, which is then placed in position in the magnetic core. While both ends of the longer laminations are shown clipped in the embodiment of the invention shown in FIG. 7, it is only necessary to clip one end, unless the other ends will interfere with the assembly of the magnetic core. FIG. 7A is a fragmentary view of the magnetic core **180** shown in FIG. 7, and given the reference numeral **180'** in FIG. 7A. FIG. 7A illustrates the adjoining portions **182** and **188**, with portion **182** modified and given the reference numeral **182'**, to illustrate that the longer laminations need not be clipped on both ends.

In summary, there has been disclosed new and improved magnetic core structures of the stacked type, and methods of constructing same. The new and improved magnetic cores have stepped-lap joints between adjoining leg and yoke portions, which are generated by changing the length dimensions of the leg and yoke laminations in opposite directions, from layer to layer across the magnetic core. This enables the magnetic cores to be assembled easier and faster, as the stepped ends of the two leg portions being joined by two yoke portions, face the assembler. Thus, it is not necessary to bend or flex the groups of yoke laminations being placed into portion, as there is no tucking under of ends required or blind placement of ends, such as encountered in prior art structures. This new and improved arrangement also eliminates frictional drag between the laminations being placed and already positioned laminations, eliminating the possibility of moving already positioned laminations.

We claim as our invention:

1. A method of constructing a magnetic core having first and second leg portions, first and second yoke portions and stepped-lap joints between the leg and yoke portions, comprising the steps of:

providing a plurality of laminations having a predetermined number of different length dimensions, with each of the laminations having parallel edges and mitered edges to define a substantially trapezoidal configuration,

providing a plurality of groups of laminations by selecting predetermined different lengths of laminations for each group, and stacking the laminations of each group according to length, with the longest and shortest laminations on opposite sides of each group, and with their parallel edges and midpoints aligned to space the ends of the laminations from one another, at each end of the group, in a progressively stepped arrangement,

orienting two of the groups of laminations to provide the first and second leg portions of the magnetic core, with the shortest laminations of the two groups facing in a predetermined direction,

orienting two of the groups of laminations to provide the first and second yoke portions of the magnetic core, with the shortest laminations of these two groups facing opposite to the predetermined direction in which the shortest laminations of the leg portions are facing,

and assembling the first and second yoke portions with the first and second leg portions to provide a first assembly, with the mitered ends of adjoining leg and yoke portions butting together to provide stepped-lap joints.

2. The method of claim **1** including the step of positioning the adjoining leg and yoke portions, along their mitered adjoining ends, to reduce the amount of void volume generated by the stepped-lap joint at the inner corners defined by adjoining leg and yoke portions.

3. The method of claim **1** including the steps of incrementally clipping at least one end of each lamination prior to the step of stacking the groups of laminations, and aligning the incrementally clipped ends of each group to establish the progressively stepped relationship of the mitered ends of each end of each group.

4. The method of claim **1** including the steps of providing a second assembly, similar to the first assembly, and superposing the second assembly on the first assembly with the longest and shortest laminations of the first and second assemblies, respectively, being in contact with one another.

5. The method of claim **1** including the steps of providing a second assembly, similar to the first assembly, and superposing the second assembly on the first assembly with the longest laminations of the first and second assembles being in contact with one another.

6. The method of claim **1** including the steps of disposing an adhesive on at least a portion of the laminations of each group, to bond each group into a coherent assembly, prior to the step of orienting the groups to provide leg and yoke portions.

7. The method of claim **1** including the steps of providing a positioning recess in each lamination, and aligning the recesses on the laminations of each group to establish the progressively stepped relationship of the mitered ends at each end of each group.

8. The method of claim **1** including the step of aligning the midpoints of the laminations of each group by placing them in a right angle fixture having two walls disposed perpendicular to one another, with the mitered ends of the laminations being placed against the two walls of the fixture.

9. The method of claim **1** including the steps of incrementally clipping the ends of only a portion of the laminations of each group, and orienting and assembling the groups with the clipped ends of the group on one side of each corner defined by adjoining leg and yoke portions, and the unclipped ends on the other side of each corner.

10. The method of claim 1 including the step of incrementally clipping at least one end of each lamination of each group, and aligning the clipped ends of each group in first and second different spaced planes, with about one-half of the laminations of each group having their clipped ends in the first plane, and the remaining laminations of the group having their clipped ends in the second plane.

11. A magnetic core, comprising:

a plurality of superposed layers of laminations,

each of said layers of laminations including at least two yoke laminations and at least two leg laminations, forming a structure having first and second spaced, parallel leg portions connected by first and second yoke portions, defining a plurality of outer corners and associated inner corners,

the yoke and leg laminations of each layer having their ends cut diagonally to provide a closed magnetic circuit having diagonal joints between adjoining ends of leg and yoke laminations,

the longitudinal dimensions of the leg and yoke laminations, between their diagonally cut ends, changing in opposite directions from layer to layer while the midpoints of the laminations in each yoke and leg portion are aligned, to offset the diagonally cut ends of the laminations in adjoining leg and yoke portions, from layer to layer, in a complementary arrangement, and provide stepped-lap joints having at least three steps in one direction before the pattern changes.

12. The magnetic core of claim 11 wherein the relative location of adjoining leg and yoke laminations, in the direction of their diagonal joint, is selected to reduce the void volume generated at the inner corners of the magnetic core structure.

13. The magnetic core of claim 11 wherein at least one end of the leg and yoke laminations are incrementally clipped, with the clipped ends of the laminations in each leg and yoke portion being aligned to establish the stepped relationship between the diagonally cut ends of each leg and yoke portion.

14. The magnetic core of claim 11 including adhesive means disposed to provide at least one coherent group of laminations in each of the leg and yoke portions.

15. The magnetic core of claim 11 wherein each lamination of each leg and yoke portion includes a positioning recess, with the positioning recesses of the laminations in each leg and yoke portion being aligned, which alignment establishes the desired stepped relationship between the diagonally cut ends of the laminations in each leg and yoke portion.

16. The magnetic core of claim 11 wherein certain of the laminations in each leg and yoke portion have at least one end incrementally clipped, and certain of the laminations are unclipped, with the clipped ends in each leg and yoke portion being aligned and disposed on the opposite side of each outer corner from the unclipped ends.

17. The magnetic core of claim 11 wherein the laminations of each leg and yoke portion are clipped on at least one end thereof, with the clipped ends of certain laminations being aligned, and the clipped ends of the remaining laminations being aligned and spaced from the other aligned clipped ends, on at least one end of each leg and yoke portion.

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