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Gumpper et al.

[11] **3,743,991**

[45] **July 3, 1973**

[54] **MAGNETIC CORE STRUCTURES**

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[21] Appl. No.: **172,849**

[52] **U.S. Cl.** **336/217**
[51] **Int. Cl.** **H01f 27/24**
[58] **Field of Search** 336/216, 217

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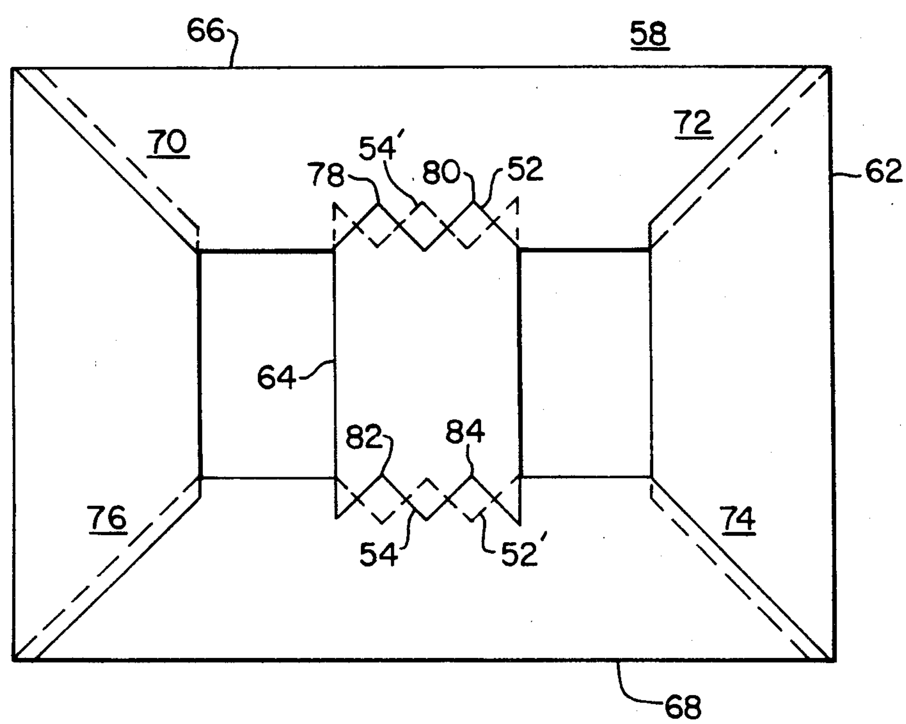
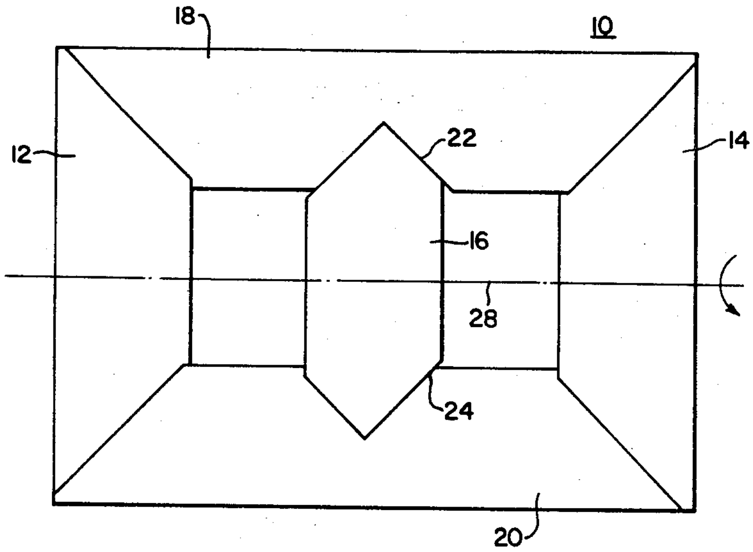
Attorney—A. T. Stratton and F. E. Browder

[57] **ABSTRACT**

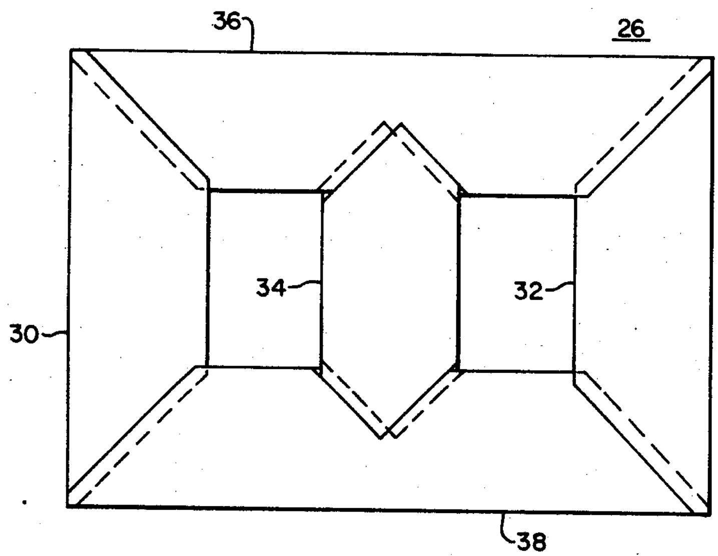
Laminated magnetic cores having leg and yoke laminations which are joined together to form lamination joints. The joints include one or more convex points at one end of a leg lamination and one or more convex or concave points at the other end of the leg lamination. The points are formed by straight portions of the joint which intersect with each other either perpendicularly, acutely or obtusely. The points at different ends of the leg lamination may or may not be aligned with each other. Distribution throughout the core may be achieved by a butted-lap arrangement or by a stepped-lap arrangement, either horizontally, vertically or angularly.

31 Claims, 15 Drawing Figures





PRIOR ART
FIG.1.



PRIOR ART
FIG.2.

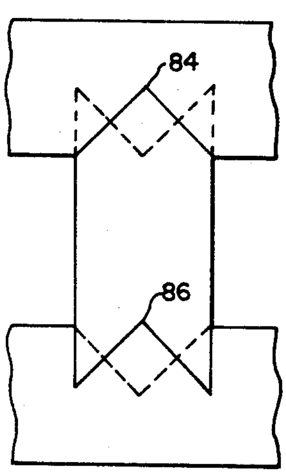


FIG.5.

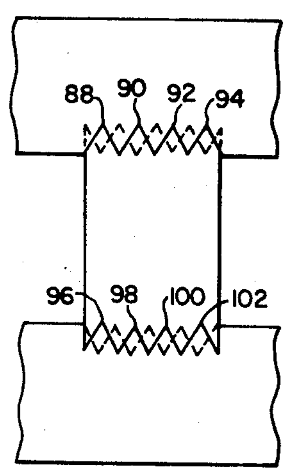


FIG.6.

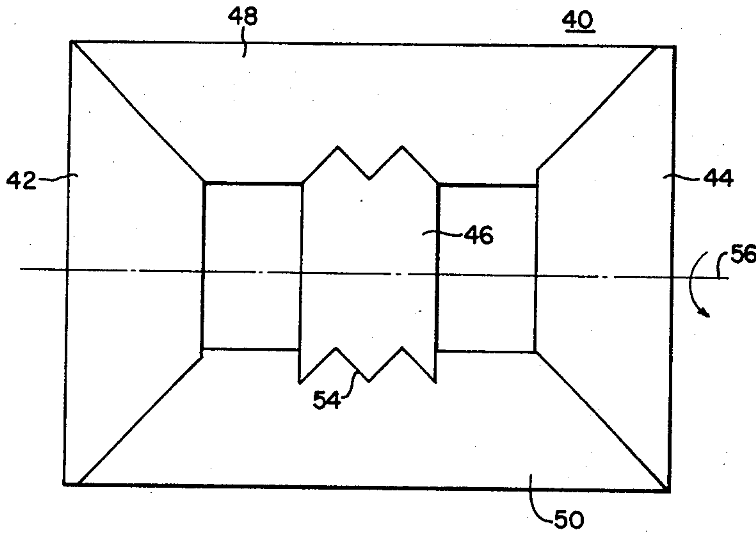


FIG. 3.

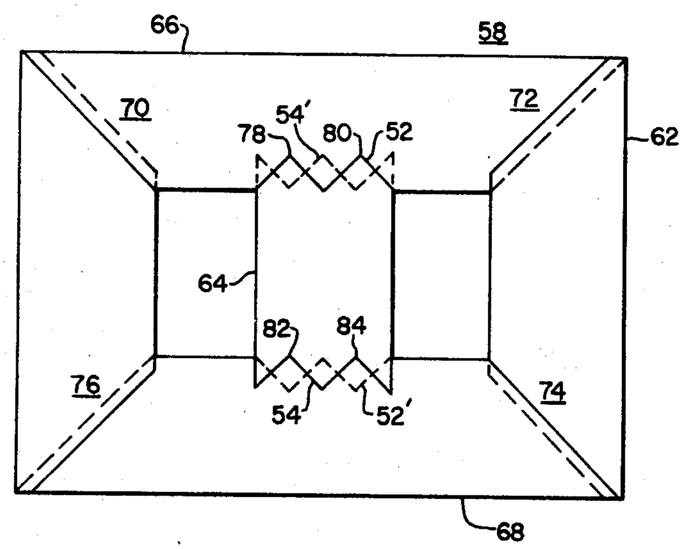


FIG. 4.

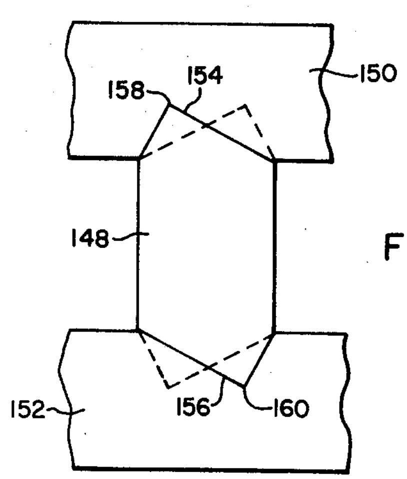


FIG. 9.

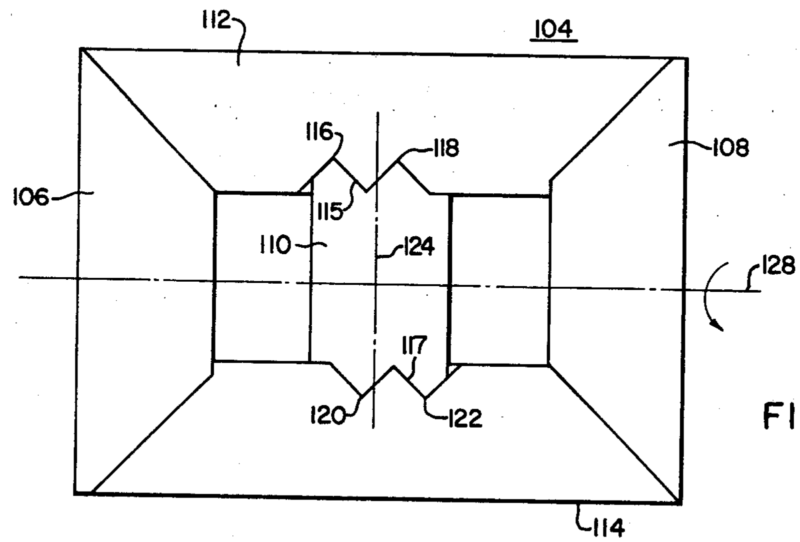


FIG. 7.

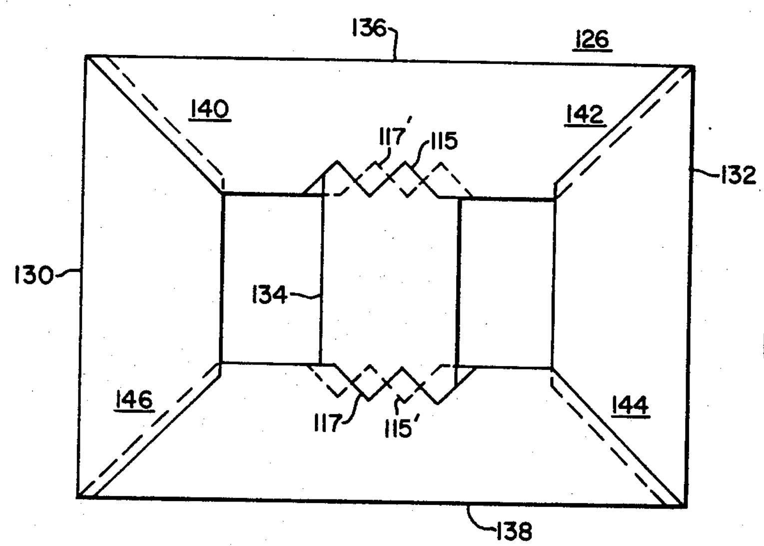


FIG. 8.

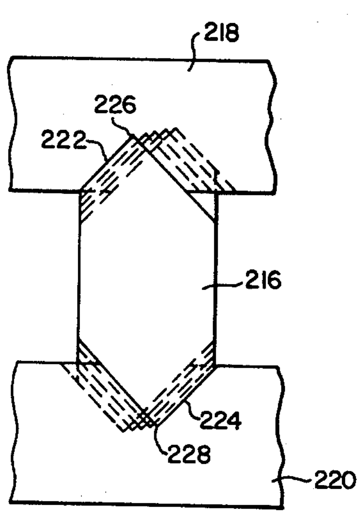


FIG. 13.

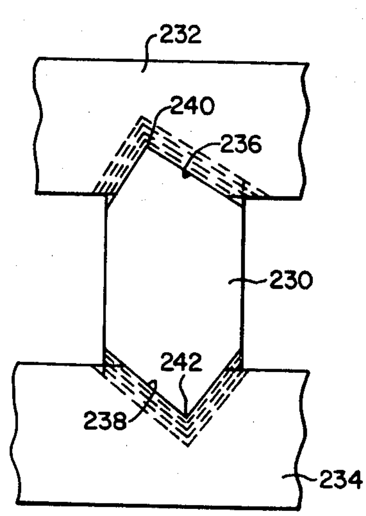


FIG. 14.

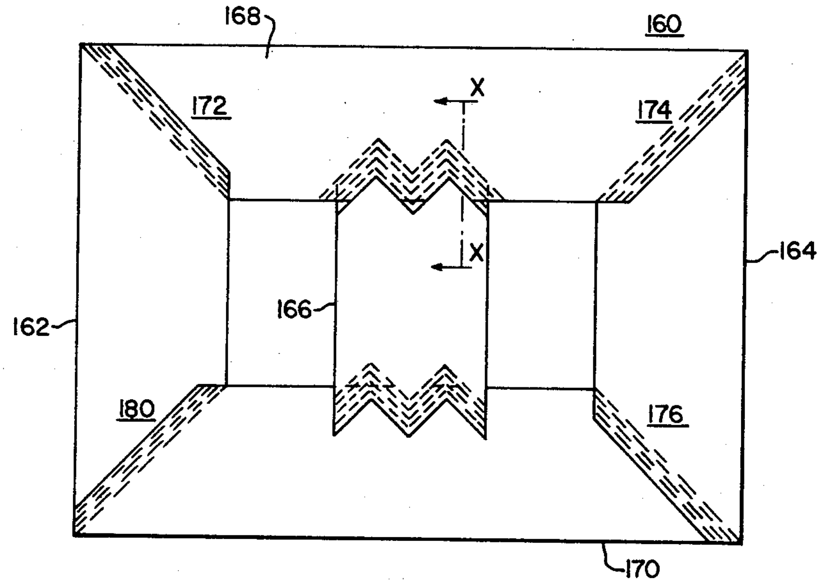


FIG. 10.

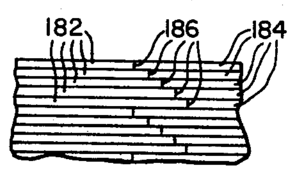


FIG. 10A.

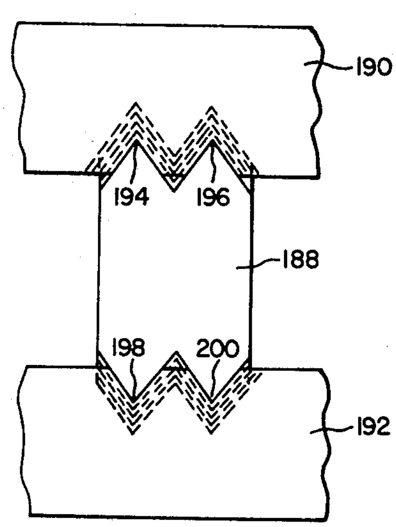


FIG. 11.

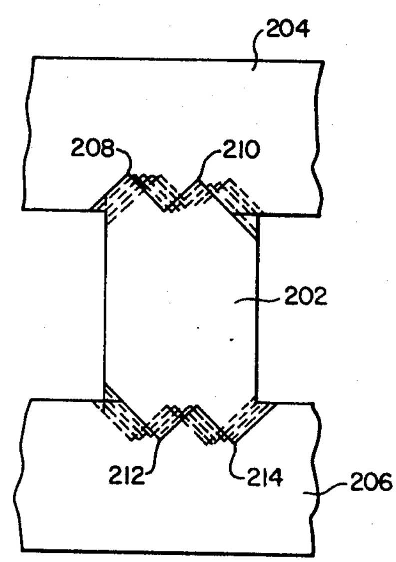


FIG. 12.

MAGNETIC CORE STRUCTURES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates, in general, to magnetic core structures and, more specifically, to laminated magnetic core structures comprising a plurality of metallic laminations.

2. Description of the Prior Art

There are several sources of losses in polyphase transformer cores in addition to the electrical steel orientation, the lamination stacking arrangement, and the air gap between the laminations. The joint regions where the flux from different legs meet, the yoke crowding effect, and the rotational flux factor at the middle leg joints all contribute adversely to the performance of the magnetic core.

Considerable research is currently being applied to the problem of producing a high performance polyphase laminated magnetic core. The problem is compounded by the necessity of weighing manufacturing and environmental considerations against the electrical performance of the core. The ease with which the laminations may be stacked, the amount of magnetic material required to fabricate the core, and the sound level produced by an energized core are a few of the considerations which must be weighed in determining the optimum arrangement for a magnetic core. While some cores are superior in several of these categories, few if any exhibit substantially all of the desirable features.

Of the many magnetic cores developed over the years, certain types have been standardized for particular applications. Although most of these cores perform extremely well, certain inherent limitations exist in some of the cores and are considered undesirable. The amount of scrap produced in punching or shearing the laminations directly affects the economic aspects of the magnetic core. The flux patterns dictated by the size and shape of the lamination joints affect the electrical performance of the magnetic core. The sound level produced by the magnetic core may determine the feasibility of using a core commercially. Unfortunately, many conventional arrangements that are suggested for improving laminated magnetic cores do not provide the improvements without creating an offsetting disadvantage in other features of the core.

It would be desirable, and it is an object of this invention, to provide a magnetic core which may be fabricated from less material than present state of the art cores. It is a further object of this invention to provide a magnetic core which exhibits better electrical characteristics at a reduced sound level than present cores. Finally, it is an object of this invention to provide a magnetic core which exhibits all of these advantageous features.

SUMMARY OF THE INVENTION

This invention discloses new and improved arrangements for constructing a laminated magnetic core. Novel arrangements are provided for the middle leg lamination geometry to improve the joint between the middle leg and the yoke laminations.

One embodiment discloses middle leg geometry having convex points at one end and concave points at the other end. Another embodiment discloses middle leg geometry having convex points at both ends with the possibility of offsetting these points.

Various arrangements may be used to define the points. They may be defined by straight portions of the joint which intersect perpendicularly, acutely or obtusely. Distribution throughout the core may be achieved by a butted-lap arrangement or by a stepped-lap arrangement, either horizontally, vertically or angularly.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. **1** is a plan view of a layer of laminations according to the prior art;

FIG. **2** is a plan view of a laminated magnetic core constructed according to the prior art;

FIG. **3** is a plan view of a layer of laminations according to the teachings of this invention illustrating multiple point middle leg lamination geometry;

FIG. **4** is a plan view of a laminated magnetic core constructed according to the teachings of this invention illustrating a butted-lap joint distribution arrangement of the layer shown in FIG. **3**;

FIG. **5** is a partial plan view of a laminated magnetic core constructed according to the teachings of this invention illustrating a middle leg lamination having a concave and a convex point;

FIG. **6** is a partial plan view of a laminated magnetic core constructed according to the teachings of this invention illustrating a middle leg lamination having a plurality of concave and convex points;

FIG. **7** is a plan view of a layer of laminations according to the teachings of this invention illustrating offset point middle leg geometry;

FIG. **8** is a plan view of a laminated magnetic core constructed according to the teachings of this invention illustrating a butted-lap joint distribution arrangement of the layers shown in FIG. **7**;

FIG. **9** is a partial plan view of a laminated magnetic core constructed according to the teachings of this invention illustrating a middle leg lamination having points formed by straight joint portions which are 60° and 30° skew to the sides of the lamination;

FIG. **10** is a plan view of a laminated magnetic core constructed according to the teachings of this invention illustrating vertical stepped-lap distribution of a middle leg lamination having two concave points and two convex points;

FIG. **10***a* is a sectional view of the lamination joints taken along line X—X shown in FIG. **10**;

FIG. **11** is a partial plan view of a laminated magnetic core constructed according to the teachings of this invention illustrating vertical stepped-lap distribution of a middle leg lamination having convex points at each end;

FIG. **12** is a partial plan view of a laminated magnetic core constructed according to the teachings of this invention illustrating horizontal stepped-lap distribution of a middle leg lamination having convex offset points;

FIG. **13** is a partial plan view of a laminated magnetic core constructed according to the teachings of this invention illustrating one form of angular stepped-lap distribution; and

FIG. **14** is a partial plan view of a laminated magnetic core constructed according to the teachings of this invention illustrating another form of angular stepped-lap distribution.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Throughout the following description similar reference characters refer to similar members in all figures of the drawings.

Referring now to the drawings, and FIG. 1 in particular, there is shown a layer of laminations **10** assembled to define a magnetic path having three legs and two windows. This arrangement is used extensively in electrical inductive apparatus at the present time. The layer of laminations **10** includes the outer leg laminations **12** and **14**, the middle leg lamination **16**, and the yoke laminations **18** and **20**. The laminations **16** and **18** are joined by a butt joint **22** which penetrates the yoke laminations **18** to its longitudinal centerline. The laminations **16** and **20** are joined by a butt joint **24** which penetrates the yoke lamination **20** to its longitudinal centerline.

A complete laminated magnetic core **26** constructed according to the prior art is illustrated in FIG. **2**. The magnetic core **26** comprises a plurality of layers of laminations which are identical to the layer illustrated in FIG. **1**. Alternate layers of laminations in the core **26** are effectively rotated about the axis **28** which is shown in FIG. **1**, thus permitting the laminations in alternate layers to lap the adjacent butt joints. This arrangement provides a butted-lap laminated magnetic core having the outer legs **30** and **32**, the middle leg **34**, and the yoke portions **36** and **38**.

Because of the geometry of the laminations which comprise the magnetic core **26**, voids are produced at the inside corners near the joints connecting the middle leg **34** and the yokes **36** and **38**. These joints cause the flux which circulates between the outer legs **30** and **32** to occupy the outer region of the yokes. The flux crowding effect in this region reduces the efficiency of the magnetic core.

An embodiment of this invention which eliminates the voids at the inside corners and reduces the flux crowding effect is illustrated in FIGS. **3** and **4**. The layer of laminations **40** shown in FIG. **3** includes the outer leg laminations **42** and **44**, the middle leg lamination **46**, and the yoke laminations **48** and **50**. The butt joint **52** connects the yoke lamination **48** to the middle leg lamination **46** and the butt joint **54** connects the yoke lamination **50** to the middle leg lamination **46**. The joints **52** and **54** have geometry which allows them to have the same joint length without penetrating the yoke laminations as much as the joint arrangement shown in FIGS. **1** and **2**. Thus, the flux crowding effect is reduced by this arrangement without sacrificing the length of the butt joint. The inside corners near the middle leg-yoke joint are voidless.

In both the joints **52** and **54**, the angles which are formed at the points of the joints are right angles. The portion of the lamination **46** which forms the butt joint **52** is automatically formed by the punching operation used in fabricating the lamination **46**. A strip of magnetic material is indexed into the punching die where a lamination **46** is punched out, leaving the end of the strip with the geometry shown. Indexing the strip to punch the next lamination produces another lamination **46**. Thus, the geometry of the lamination **46** permits it to be fabricated without producing any scrap material.

The laminated magnetic core **58** which is shown in FIG. **4** is constructed by stacking layers of laminations with the edges of the layers in alignment. The layers are similar to the layer **40** illustrated in FIG. **3** with alternate layers rotated around the axis **56**. The resulting magnetic core **58** is of the butted-lap type and includes the outer legs **60** and **62**, the middle leg **64**, and the yokes **66** and **68**. The joint **52** is adjacent to the joint **54'**, where the prime mark denotes the joint in an inverted layer of laminations. Similarly, the joint **54** is adjacent to the joint **52'**. These joints, which are in adjacent layers, are effectively perpendicular to each other where they cross. The adjacent joints cross at approximately the middle of the 45° mitered portions of the joints.

The laminated magnetic core **58** which is provided by this lamination stacking arrangement is voidless, has low flux crowding effects and may be fabricated without any middle leg punching scrap. Scrap loss for the entire core, due mainly to the middle leg scrap savings, is approximately 1.9 percent of the core material required for a 45 KVA transformer. This is very favorable as compared to the 7.3 percent loss for a similarly rated core constructed according to the prior art.

Although the outer leg-yoke joints have been specifically illustrated in FIG. **4**, the laminations may be punched with other corner joint shapes without departing from the teachings of the invention. For instance, the corner joints illustrated in FIG. **2** may be used. Similarly, it is within the contemplation of this invention that the number of points defined by the geometry of the middle leg lamination may be different than that shown in FIG. **4**.

A point is formed by the mitered portion of the joint. A point is convex when it is formed by mitered portions which form an acute included angle with a lamination side. A point is concave when it is formed by mitered portions which form an obtuse included angle with a lamination side. Thus, the joint **52** includes the convex points **78** and **80** and the joint **54** includes the concave points **82** and **84**. The convex points **78** and **80** and the concave points **82** and **84** are formed by mitered portions of the joints which are perpendicular to each other. Therefore, they are referred to as right angle convex and right angle concave points, respectively.

A core having a middle leg lamination which includes one right angle convex point **84** at one end and one right angle concave point **86** at the other end is partially illustrated in FIG. **5**. Alternate layers of laminations are rotated so that the adjacent mitered portions of the middle leg-yoke joints properly cross each other.

The angles which are formed by the mitered portions of the joints may also be other than right angles. A core having a mitered middle leg lamination which includes convex points **88, 90, 92** and **94** at one end and concave points **96, 98, 100** and **102** at the other end, is partially illustrated in FIG. **6**. Since the mitered portions of the joints intersect each other to form angles which are less then right angles, the convex points **88, 90, 92** and **94** are referred to as acute angle convex points. Similarly, the points **96, 98, 100** and **102** are referred to as acute angle concave points. Other embodiments of the invention may include more or less points and/or obtuse angle points.

A layer of laminations **104** which includes a middle leg lamination with offset convex points is illustrated in FIG. **7**. The layer **104** comprises the outer leg laminations 106 and 108, the middle leg lamination 110, and the yoke laminations 112 and 114. One end of the lamination 110 has geometry which produces a joint having right angle convex points 116 and 118. The other end of the lamination 110 has geometry which produces right angle convex points 120 and 122. Respective points at each end of the lamination are offset so that the location of each point is at a different predetermined distance from the lamination axis 124.

A laminated magnetic core 126 having middle leg laminations which include offset right angle points is illustrated in FIG. 8. The core 126 is constructed by stacking layers of laminations with the edges of the layers in alignment. The layers comprising the magnetic core 126 are similar to the layer 104 shown in FIG. 7 with alternate layers rotated around the axis 128. The laminations comprising the core 126 define the outer legs 130 and 132, the middle leg 134, and the yokes 136 and 138. The outer corner joints 140, 142, 144 and 146 connect the yoke laminations to the other leg laminations. Other corner joint arrangements may be used, such as those illustrated in FIG. 2. The middle leg joints 115 and 117′, which are in adjacent layers, cross each other perpendicularly. The middle leg joints 115′ and 117 similarly cross each other. The joint points in adjacent layers are not adjacent due to the offsetting geometry of the middle leg laminations.

The unique geometry of the middle leg laminations enables the middle leg laminations to be fabricated without producing any material scrap. This feature greatly improves the percentage of scrap produced in fabricating the laminations for the magnetic core 126 over conventional cores. For 45 KVA transformers, there is a material savings of 3.6 percent with the magnetic core 126 compared to the magnetic core 26 illustrated in FIG. 2. In addition, the flux crowding in the yokes 136 and 138 is reduced without reducing the joint contact length. The points may be either acute angle points or obtuse angle points rather than right angle points and more or less than the number of points illustrated may be used without departing from the spirit of the invention.

Other embodiments of the offset point middle leg arrangement may be apparent to one skilled in the art after reading the teachings of this invention. FIG. 9 illustrates one embodiment where the middle leg lamination 148 joins the yoke laminations 150 and 152 with the joints 154 and 156, respectively. The joint 154 comprises two mitered portions which intersect to form the right angle point 158. The two mitered portions form different angles with the edges of the lamination 148. Various acute angles may be used, such as the 60° and 30° angles illustrated in FIG. 9. The joint 156 is similarly shaped except that the right angle point 160 is offset from the point 158, that is, one point is not coincident with a line drawn through the other point and parallel to the longitudinal axis of the lamination 148. Point angles other than right angles may be used. The magnetic core which is partially illustrated in FIG. 9 employs the offset point arrangement and may be constructed with 2.4 percent less material than the conventional magnetic core illustrated in FIG. 2. The decreased penetration of the joints into the yoke laminations reduces the flux crowding effect and the core produced is voidless.

The novel arrangements of the magnetic cores disclosed herein and those contemplated by the invention may be employed in stepped-lap type laminated magnetic cores. Stepped-lap joints substantially improve the performance of a magnetic core compared to magnetic cores which utilize the conventional butted-lap type joint. The core loss is lowered, the exciting voltage-ampere requirements are reduced, and the sound level of the magnetic core has a lower intensity. In a stepped-lap joint, the joints between the mitered or diagonal ends of the leg and yoke laminations in each layer of laminations are incrementally offset from similarly located joints in adjacent layers by a predetermined stepped or progressive pattern, with the joints being stepped at least three times in one direction before the direction is changed or the pattern is repeated.

FIG. 10 illustrates an embodiment of the invention wherein a laminated magnetic core 160 has stepped-lap joints and a middle leg lamination having right angle concave and convex points. The core 160 comprises the outer legs 162 and 164, the middle leg 166, and the yokes 168 and 170. The outer corner stepped-lap joints 172, 174, 176 and 180 connect the yoke laminations to the outer leg laminations. The geometry of the laminations which form the middle leg 166 is similar to that of the middle leg lamination shown in FIG. 3. The middle leg laminations are vertically distributed in a stepped-lap pattern by progressively notching one yoke lamination deeper and the other yoke lamination shallower than in the adjacent layer. The middle leg lamination is moved between the yoke laminations in the completed core without changing the dimensions of the middle leg lamination. Voids which exist in the yoke-middle leg joints are distributed between the yoke and the middle leg portions of the core.

Various arrangements of step lapping the joints may be used. FIG. 10A, which is a sectional view of FIG. 10 taken at the line X—X, illustrates one arrangement of step lapping the joints. The middle leg laminations 182 are butted against the yoke laminations 184, with the butt joints 186 incrementally offset from layer-to-layer with four layers of laminations separating repeating joints in the same plane. This arrangement of stepped-lap joints is also illustrated in FIGS. 11, 12, 13 and 14, however, any other stepped-lap arrangement may be used without departing from the scope of the invention.

The stepped-lap distribution illustrated in FIG. 10 is achieved by incrementing the joints in a direction parallel to a straight side of the middle leg, hence the terminology "vertical" distribution. Another form of vertically distributing the joints is illustrated in FIG. 11. The length of the lamination 188 is changed to progressively step the joints into the yoke laminations 190 and 192. The convex points 194, 196, 198 and 200 are formed by the intersection of the straight portions of the joints. The angles illustrated are acute, however, obtuse or right angles may also be used.

FIG. 12 illustrates a middle leg arrangement of a laminated magnetic core which is horizontally stepped-lapped. The middle leg lamination 202 has offset convex points which are shifted horizontally throughout the core due to the dimensional changes of the middle leg laminations in adjacent layers.

FIG. 13 illustrates a middle leg arrangement of a laminated magnetic core which is angularly stepped-lapped, that is, the joints progress in a direction which is between the horizontal and vertical directions. In FIG. 13, the leg lamination 216 butts against the yoke laminations 218 and 220 to form the joints 222 and

224. The joints and the offset convex points 226 and 228 progress into the yoke laminations 218 and 220 from layer-to-layer in an angular fashion. Another angularly distributed stepped-lapped joint arrangement is shown in FIG. 14. Here, the angle of progression is more nearly vertical than that shown in FIG. 13. The leg lamination 230 connects the yoke laminations 232 and 234 with the joints 236 and 238. A line drawn through either of the concave points 240 and 242 and its respective points in adjacent layers will indicate the direction of distribution. In all of the stepped-lap arrangements described and contemplated herein, laminations may be stacked in groups and the groups may be stacked with alternate groups reversed. This procedure increases the joint distribution throughout the core.

The laminated magnetic cores described herein offer several performance improvements over prior art designs. Tests performed on several of the different embodiments of the invention indicate the superior performance of the core arrangements disclosed.

A 45 KVA core constructed with the middle leg arrangement shown in FIG. 11 and with the outer corner arrangements shown in FIG. 10 was tested and compared to the standard prior art arrangement shown in FIG. 2. At an induction level of 15 kilogauss, the true watts per pound loss was improved by 33 percent, the apparent watts per pound loss was improved by 63 percent and the sound level was improved by 3.4 db over the prior art core. By constructing the core according to this arrangement to provide the same performance as the prior art core, a core steel savings of 9.7 percent can be realized along with a conductor material savings of 2 percent.

A 45 KVA core constructed with the middle leg arrangement shown in FIG. 11, except with four convex points on each end of the middle leg lamination, and with the outer corner arrangements shown in FIG. 10, was tested and compared to the standard prior art arrangement shown in FIG. 2. At an induction level of 15 kilogauss, the true watts per pound loss was improved by 30 percent, the apparent watts per pound loss was improved by 56 percent, and the sound level was improved by 4.0 db over the prior art core. Core steel savings of 11.5 percent and copper savings of 2 percent could be realized with this core arrangement.

A 45 KVA core constructed with the middle leg arrangement shown in FIG. 14 and with the outer core arrangements shown in FIG. 10 was tested and compared to the standard prior art arrangement shown in FIG. 2. At an induction level of 15 kilogauss, the true watts per pound loss was improved by 36 percent, the apparent watts per pound was improved by 69 percent, and the sound level was improved by 3.4 db over the prior art core. Core steel savings of 8.3 percent and copper savings of 2 percent could be realized by using this core arrangement.

Since numerous changes may be made in the above described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all of the matter contained in the foregoing description, or shown in the accompanying drawings, shall be interpreted as illustrative rather than limiting.

We claim as our invention:

1. A laminated magnetic core comprising a plurality of layers of laminations, said layers stacked with their edges in alignment to define a core having at least three legs and two yokes, each of said layers of laminations comprising a lamination having two straight sides and first and second ends, said first end defining a first joint between said lamination and one of said yokes, said second end defining a second joint between said lamination and the other of said yokes, said first joint comprising at least one convex point which is formed by the intersection of two straight portions of said first joint, said second joint comprising at least one concave point which is formed by the intersection of two straight portions of said second joint, said convex and concave points being equally spaced from the lamination axis which is parallel to the sides and coincident with the center of the lamination, said first and second joints being distributed with respect to the joints in the other layers, with at least one layer of laminations separating repeating joints in the same plane.

2. The laminated magnetic core of claim 1 wherein the first joint of the layer of laminations comprises a plurality of convex points and the second joint of the layer of laminations comprises a plurality of concave points with the respective convex and concave points being equally spaced from the lamination axis.

3. The laminated magnetic core of claim 1 wherein the concave and convex points are formed by straight portions of the joint which intersect to form a right angle.

4. The laminated magnetic core of claim 1 wherein the concave and convex points are formed by straight portions of the joint which intersect to form an acute angle.

5. The laminated magnetic core of claim 1 wherein the concave and convex points are formed by straight portions of the joint which intersect to form an obtuse angle.

6. The laminated magnetic core of claim 1 wherein the concave and convex points are formed by straight portions of the joint which intersect to form a right angle, a first of the straight portions being skew to one side of the lamination by substantially 30°, a second of the straight portions being skew to the other side of the lamination by substantially 60°.

7. The laminated magnetic core of claim 1 wherein adjacent layers of laminations are identical and are rotated 180° around an axis to form a butted-lap core with the points of the joints maintaining their spacing from the lamination axis.

8. The laminated magnetic core of claim 1 wherein the joints are incrementally offset from layer-to-layer in a predetermined stepped-lap pattern with at least two layers of laminations separating repeating joints in the same plane.

9. The laminated magnetic core of claim 8 wherein the joints are incrementally offset from layer-to-layer without changing the dimensions of the middle leg lamination.

10. The laminated magnetic core of claim 8 wherein the predetermined stepped-lapped pattern progresses only in a horizontal direction.

11. The laminated magnetic core of claim 8 wherein the predetermined stepped-lapped pattern progresses only in a vertical direction.

12. The laminated magnetic core of claim 8 wherein the predetermined stepped-lapped pattern progresses only in an angular direction.

13. A laminated magnetic core comprising a plurality of layers of laminations, said layers stacked with their edges in alignment to define a core having at least three legs and two yokes, each of said layers of laminations comprising a lamination having two straight sides and first and second ends, said first end defining a first joint between said lamination and one of said yokes, said second end defining a second joint between said lamination and the other of said yokes, said first joint comprising a first convex point which is formed by the intersection of two straight portions of said first joint, said second joint comprising a second convex point which is formed by the intersection of two straight portions of said second joint, said first and second convex points being equally spaced from and on the same side of the lamination axis which is parallel to the sides and coincident with the center of the lamination, said first and second joints being distributed with respect to the joints in the other layers with the joints incrementally offset from layer-to-layer in a predetermined stepped-lap pattern with at least two layers of laminations separating repeating joints in the same plane.

14. The laminated magnetic core of claim **13** wherein the first joint of the layers of laminations comprises a plurality of convex points, the second joint of the layer of laminations comprises a plurality of convex points, with the respective convex points being equally spaced from the lamination axis.

15. The laminated magnetic core of claim **13** wherein the convex points are formed by straight portions of the joint which intersect to form a right angle.

16. The laminated magnetic core of claim **13** wherein the convex points are formed by straight portions of the joint which intersect to form an acute angle.

17. The laminated magnetic core of claim **13** wherein the convex points are formed by straight portions of the joint which intersect to form an obtuse angle.

18. The laminated magnetic core of claim **13** wherein the convex points are formed by straight portions of the joint which intersect to form a right angle, a first of the straight portions being skew to one side of the lamination by substantially 30°, a second of the straight portions being skew to the other side of the lamination by substantially 60°.

19. The laminated magnetic core of claim **13** wherein the predetermined stepped-lap pattern progresses only in a horizontal direction.

20. The laminated magnetic core of claim **13** wherein the predetermined stepped-lap pattern progresses only in a vertical direction.

21. The laminated magnetic core of claim **13** wherein the predetermined stepped-lap pattern progresses only in an angular direction.

22. A laminated magnetic core comprising a plurality of layers of laminations, said layers stacked with their edges in alignment to define a core having at least three legs and two yokes, each of said layers of laminations comprising a lamination having two straight sides and first and second ends, said first end defining a first joint between said lamination and one of said yokes, said second end defining a second joint between said lamination and the other of said yokes, said first joint comprising a plurality of convex points which are formed by the intersection of straight portions of said first joint, said second joint comprising a plurality of convex points which are formed by the intersection of straight portions of said second joint, the convex points in said first joint which are on one side of the lamination axis, which is parallel to the sides and coincident with the center of the lamination, being spaced from the lamination axis by distances which are unequal to the distances with which respective convex points in said second joint which are on the same side of the lamination axis and spaced therefrom, said first and second joints being distributed with respect to the joints in the other layers with at least one layer of laminations separating repeating joints in the same plane.

23. The laminated magnetic core of claim **22** wherein the convex points are formed by straight portions of the joint which intersect to form a right angle.

24. The laminated magnetic core of claim **22** wherein the convex points are formed by straight portions of the joint which intersect to form an acute angle.

25. The laminated magnetic core of claim **22** wherein the convex points are formed by straight portions of the joints which intersect to form an obtuse angle.

26. The laminated magnetic core of claim **22** wherein the convex points are formed by straight portions of the joint which intersect to form a right angle, a first of the straight portions being skew to one side of the lamination by substantially 30°, a second of the straight portions being skew to the other side of the lamination by substantially 60°.

27. The laminated magnetic core of claim **22** wherein adjacent layers of laminations are identical and are rotated 180° around an axis to form a butted-lap core with the points of the joints maintaining their spacing from the lamination axis.

28. The laminated magnetic core of claim **22** wherein the joints are incrementally offset from layer-to-layer in a predetermined stepped-lap pattern with at least two layers of laminations separating repeating joints in the same plane.

29. The laminated magnetic core of claim **28** wherein the predetermined stepped-lap pattern progresses only in the horizontal direction.

30. The laminated magnetic core of claim **28** wherein the predetermined stepped-lap pattern progresses only in the vertical direction.

31. The laminated magnetic core of claim **28** wherein the predetermined stepped-lap pattern progresses only in an angular direction.

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