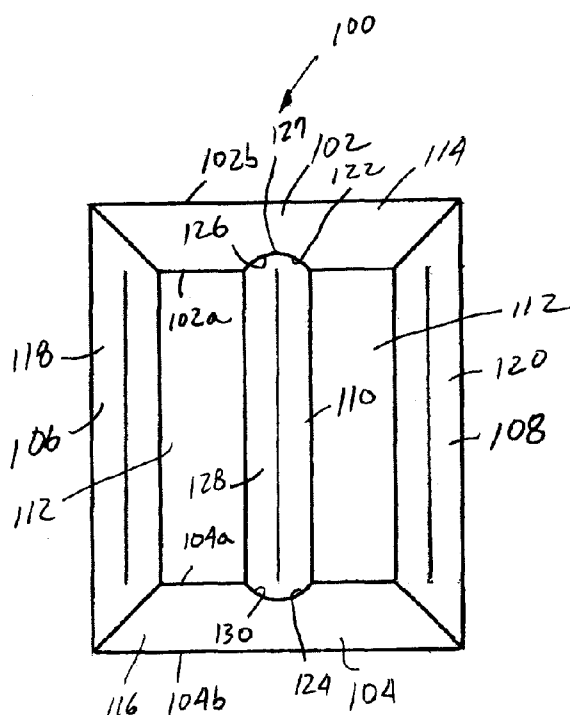




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[Continued on next page]

- (54) Title: RADIUS CUT TRANSFORMER CORE CONFIGURATION FOR STEP LAP YOKE AND CENTRAL LEG



(57) Abstract: A transformer core includes a plurality of first and second outer leg plates (106, 108), a plurality of inner leg plates (110), each having opposing, arc-shaped ends (122, 124), and a plurality of upper yoke plates and a plurality of lower yoke plates (102, 104). Each of the upper and lower yoke plates has an outer side and an inner side with an arc-shaped notch formed in the inner side (129, 130). The inner leg plates, the upper and lower yoke plates, and the first and second outer leg plates are joined to form first and second outer legs from the first and second outer leg plates, respectively; an upper yoke and a lower yoke from the upper and lower yoke plates, respectively; and a central leg from the inner leg plates, with each arc-shaped end of the inner leg plates being joined with an associated arc-shaped notch of each of the upper and lower yoke plates.



TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,  
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— *as to the applicant's entitlement to claim the priority of  
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**RADIUS CUT TRANSFORMER CORE CONFIGURATION  
FOR STEP LAP YOKE AND CENTRAL LEG**

**[0001]**     FIELD OF THE INVENTION

**[0002]**     The invention relates to transformers and more particularly, to transformers having a stacked core and methods of making the same with reduced waste and improved core performance.

**[0003]**     BACKGROUND OF THE INVENTION

**[0004]**     A stacked transformer core is comprised of thin metallic laminate plates, such as grain oriented silicon steel. This type of material is used because the grain of the steel may be groomed in certain directions to reduce the magnetic field loss. The plates are stacked on top of each other to form a plurality of layers. A stacked core is typically rectangular in shape and can have a rectangular or cruciform cross-section. A front view of a conventional three leg stacked core 10 for a three phase transformer is shown in FIG. 1. The core 10 comprises an upper yoke 12, a lower yoke 14, an inner leg 16, and first and second outer legs 18, 20. A pair of windows 22 are disposed between the inner leg 16 and the first and second outer legs 18, 20, respectively. Wire coils (not shown) are mounted to the inner leg 16 and the first and second outer legs 18, 20, respectively.

**[0005]**     The upper yoke 12 comprises a stack of plates 24, the lower yoke 14 comprises a stack of steel plates 26, the first outer leg 18 comprises a stack of plates 28 and the second outer leg 20 comprises a stack of plates 30. The plates 24, 26 of the upper and lower yokes 12, 14 have opposing ends that form joints with opposing ends of the plates 28, 30 of the first and second outer legs 18, 20, respectively. A V-shaped upper notch 32 is formed in each of the plates 24 of the upper yoke 12 and a V-shaped lower notch 36 is formed in each of the plates 26 of the lower yoke 14. The upper notches 32 form an upper groove 38 in the upper yoke 12, while the lower notches 36 form a lower groove 40 in the lower yoke 14. The size

of the individual plates 24-30 vary depending on the stacking technique used to assemble the core 10.

[0006] The inner leg 16 comprises a stack of plates 42. Each of the plates 42 has an upper tined end 42a formed by a pair of miter cuts and a lower tined end 42b formed by a pair of miter cuts. The upper and lower tined ends 42a, b of the plates 42 provide the inner leg 16 with upper and lower tined ends 16a, b, which are adapted for receipt in the upper and lower grooves 38, 40 of the upper and lower yokes 12, 14, respectively.

[0007] The manufacture of the conventional core 10 described above results in a significant amount of steel being cut away and discarded. For example, during the manufacture of the inner leg 16, four pieces of steel must be cut away from each plate 42 to provide the plate 42 with tined ends.

[0008] There is a need to provide a stacked transformer core and method of making the same that reduces the amount of steel that is scrapped and, thus, wasted.

[0009] SUMMARY OF THE INVENTION

[0010] An object of the invention is to fulfill the need referred to above. In accordance with the principles of the present invention, this objective is achieved by providing a transformer core including a plurality of first and second outer leg plates, a plurality of inner leg plates, each having opposing, arc-shaped ends, and a plurality of upper yoke plates and a plurality of lower yoke plates. Each of the upper and lower yoke plates has an outer side and an inner side with an arc-shaped notch formed in the inner side. The inner leg plates, the upper and lower yoke plates, and the first and second outer leg plates are joined to form first and second outer legs from the first and second outer leg plates, respectively; an upper yoke and a lower yoke from the upper and lower yoke plates, respectively; and a central leg from the inner leg plates, with each arc-shaped end of the inner leg plates being joined with an associated arc-shaped notch of each of the upper and lower yoke plates.

[0011] In accordance with yet another aspect of the invention, a method of making a core for a transformer provides a plurality of first and second outer leg plates; a plurality of inner leg plates, each having opposing, arc-shaped ends; and a plurality of upper yoke plates and a plurality of lower yoke plates. Each of the upper and lower yoke plates has an outer side and an inner side with an arc-shaped notch formed in the inner side. The method joins the inner leg plates, the upper and lower yoke plates and the first and second outer leg plates to form first and second outer legs from the first and second outer leg plates, respectively; an upper yoke and a lower yoke from the upper and lower yoke plates, respectively; and a central leg from the inner leg plates, with each arc-shaped end of the inner leg plates being joined with an associated arc-shaped notch of each of the upper and lower yoke plates.

[0012] Other objects, features and characteristics of the present invention, as well as the methods of operation and the functions of the related elements of the structure, the combination of parts and economics of manufacture will become more apparent upon consideration of the following detailed description and appended claims with reference to the accompanying drawings, all of which form a part of this specification.

[0013] BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The invention will be better understood from the following detailed description of the preferred embodiments thereof, taken in conjunction with the accompanying drawings wherein like numbers indicate like parts, in which:

[0015] FIG. 1 shows a front elevational view of a prior art transformer core.

[0016] FIG. 2 shows a front elevational view of a transformer core constructed in accordance with an embodiment of the invention.

[0017] FIG. 3 shows an enlarged view of a portion of central leg of the core of FIG. 2, shown spaced above a lower yoke.

[0018] DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0019] With reference to FIG. 2, a core 100 is shown for a transformer, such as a distribution transformer. The transformer may be an oil-filled transformer, i.e., cooled by oil, or a dry-type transformer, i.e., cooled by air. The core 100 has a rectangular shape and generally comprises an upper yoke 102, a lower yoke 104, first and second outer legs 106, 108 and a central leg 110 disposed generally centrally between the outer legs. Upper ends of the first and second outer legs 106, 108 are connected to first and second ends of the upper yoke 102, respectively, while lower ends of the first and second outer legs 106, 108 are connected to first and second ends of the lower yoke 104. The central leg 110 is disposed about midway between the first and second outer legs 106, 108 and has an upper end connected to the upper yoke 102 and a lower end connected to the lower yoke 104. With this construction, two windows 112 are formed between the central leg 110 and the first and second outer legs 106, 108.

[0020] The upper yoke 102 has an inner side 102a and an outer side 102b, and the lower yoke 104 has an inner side 104a and an outer side 104b. The upper yoke 102 comprises a stack of yoke plates 114, while the lower yoke 104 comprises a stack of yoke plates 116. Both the plates 114 and the plates 116 are arranged in groups. In one exemplary embodiment of the present invention, the groups are groups of seven, but for ease of illustration, four groups are shown and described herein. Of course, groups of different numbers may be used. Each of the plates 114, 116 is composed of grain-oriented silicon steel and has a thickness in a range of from about 7 mils to about 14 mils, with the particular thickness being selected based on the application of the transformer. The plates 114, 116 each have a unitary construction and are trapezoidal in shape. In each of the plates 114, 116, opposing ends of the plate 114, 116 are mitered at oppositely-directed angles of about 45 degrees thereby providing the plate 114, 116 with major and minor side edges. The plates 114 have the same width to provide the upper yoke 102 with a rectangular cross-section and the plates 116 have the same width to provide the lower yoke 104 with a rectangular cross-section. However, the lengths of the plates 114 are not all the same and the lengths of the plates 116

are not all the same. More specifically, the lengths within each group of plates 114 are different and the lengths within each group of plates 116 are different. The pattern of different lengths is the same for each group of plates 114 and the pattern of different lengths is the same for each group of plates 116. The difference in lengths within each group permits the formation of multi-step lap joints with plates 118, 120 of the first and second outer legs 106, 108.

[0021] With reference to FIG. 2, an upper arc-shaped notch 122 is formed in each inner side 102a of the plates 114 of the upper yoke 102 and an arc-shaped lower notch 124 is formed in each inner side 104a of the plates 116 of the lower yoke 104. The upper interior edges 126 (defining the notches 122) in adjacent plates 114 of the upper yoke 102 have different depths for forming vertical lap joints with upper ends 127 of inner leg plates 128 of the central inner leg 110, as will be described more fully below. Similarly, and as best shown in FIG. 3, the lower interior edges 130 in adjacent plates 116 -116c of the lower yoke 104 have different depths for forming vertical lap joints with lower ends 129 of the inner leg plates 128 of the central leg 110, as will be described more fully below.

[0022] The first outer leg 106 comprises a stack of the plates 118, while the second outer leg 108 comprises a stack of the plates 120. Both the plates 118 and the plates 120 are arranged in groups of the same number as the plates 114, 116. Each of the plates 118, 120 is composed of grain-oriented silicon steel and has a thickness in a range of from about 7 mils to about 14 mils, with the particular thickness being selected based on the application of the transformer. The plates 118, 120 each have a unitary construction and are trapezoidal in shape. In each of the plates 118, 120, opposing ends of the plate are mitered at oppositely-directed angles of about 45 degrees, thereby providing the plate 118, 120 with major and minor side edges. The plates 118 have the same width to provide the first outer leg 106 with a rectangular cross-section and the plates 120 have the same width to provide the second outer leg 108 with a rectangular cross-section. However, the lengths of the plates 118 are not all the same and the lengths of the plates 120 are not all the same. More specifically, the lengths within each group of plates 118 are different and the lengths within each group of plates 120 are different. The pattern of different lengths is the same for each group of plates

118 and the pattern of different lengths is the same for each group of plates 120. The difference in lengths within each group permits the formation of the multi-step joints with the plates 114, 116 of the upper and lower yokes 102, 104, as will be described more fully below.

[0023] Referring now to FIG. 3, there is shown an enlarged view of a portion of the lower end of the central leg 110 spaced from the lower yoke 104. When the lower end of the central leg 110 is assembled to the lower yoke 104, the convex arc-shaped ends 129 of first, second, third and fourth inner leg plates 128, 128a, 128b and 128c abut (form joints with) the concave arc-shaped lower interior edges 130 of first, second, third and fourth plates 116, 116a, 116b, and 116c of the lower yoke 104, respectively. The first through fourth inner leg plates 128-128c are vertically offset such that lower ends thereof are located successively farther downward. In order to accommodate these differences in length, the lower interior edges of the plates 116-116c are cut successively deeper. With this construction, the first plate 116 overlaps the joints between the second inner leg plates 128a and the second plate 116a, the second plate 116a overlaps the joints between the third inner leg plates 128b and the third plate 116b, and the third plate 116b overlaps the joints between the fourth inner leg plates 128cd and the fourth plate 116c. Although not shown, additional groups of the plates 116 and inner leg plates 128 are provided and repeat the pattern of the first through fourth plates 128-128c and the first through fourth plates 116-116c. In this manner, multi-step lap joints are formed between the plates 116 of the lower yoke 104 and the inner leg plates 128, with plates 116 of the lower yoke 104 overlapping plates 128.

[0024] Since the lower ends of the first through fourth inner leg plates 128-128c are located successively farther downward, upper ends of the first through fourth inner leg plates 128-128c are located successively farther downward. As a result, the upper interior edges 126 (and, thus, the upper notches 122) of the plates 114 within each group are successively shallower, which is the inverse of the lower yoke 104. With this construction, vertical multi-step lap joints are formed between the plates 114 of the upper yoke 102 and the inner leg plates 128 in the manner similar to that described above with regard to the lower yoke 104.

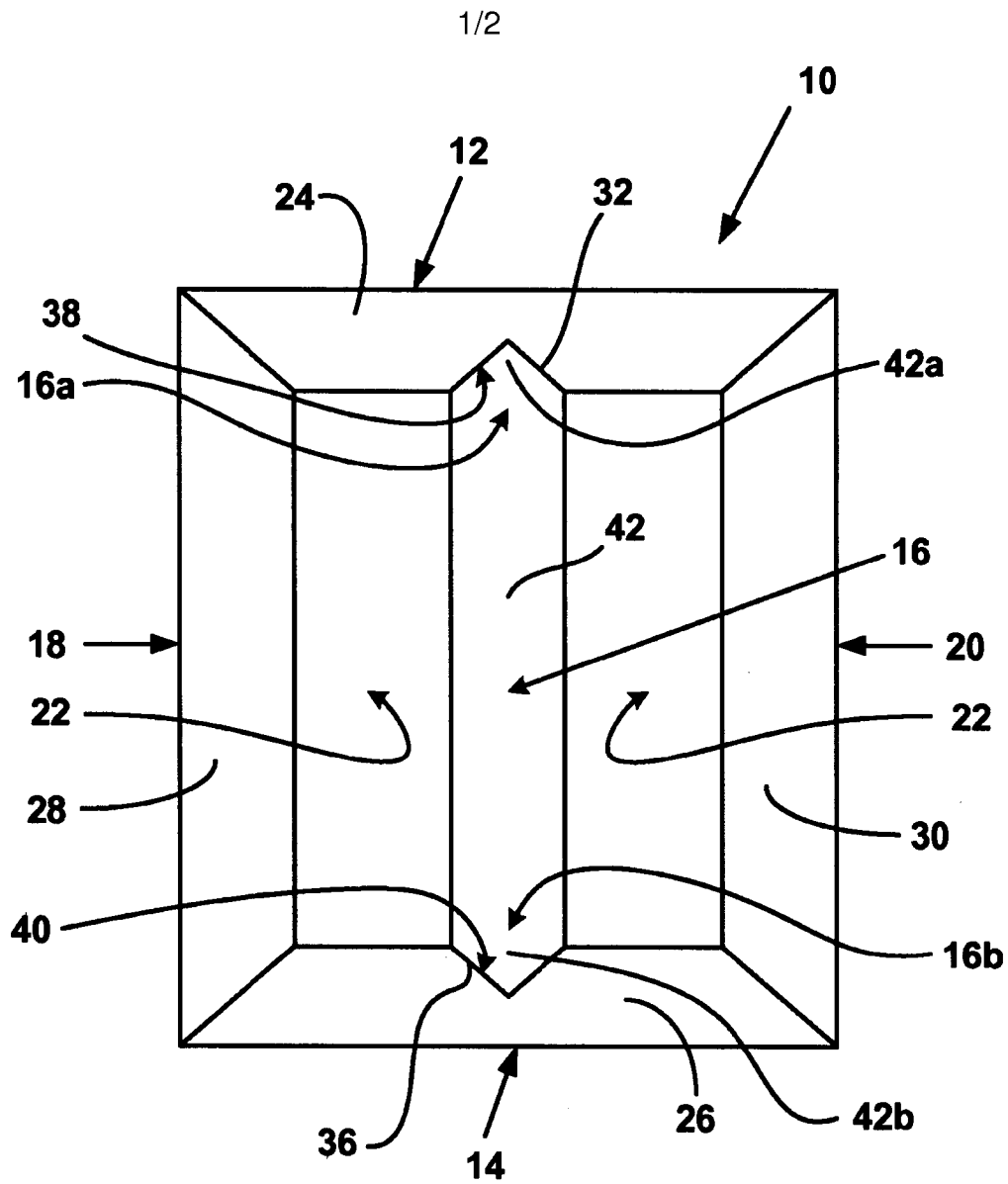
- [0025] It should be appreciated that the inner leg plates 128 may be offset differently so as to have plates 114 of the upper yoke 102 overlapping inner leg plates 128, and inner leg plates 128 overlapping plates 116 of the lower yoke 104. In addition, the inner leg plates 128 may be offset to form a seven or other number step lap joint pattern, instead of the four step lap joint pattern.
- [0026] In the embodiment where the inner leg plates 128 have different lengths, such as four different lengths, vertical multi-step lap joints are formed between the plates 114, 116 of the upper and lower yokes 102, 104 in a manner similar to that described above, however, the upper interior edges 126 (and thus the upper notches 122) of the plates 114 of the upper yoke 102 may have the same arrangement as the lower interior edges 130 (and thus the lower notches 124) of the plates 116 of the lower yoke 104 with regard to depth, because there is no vertical shifting of the inner leg plates 128.
- [0027] Plates of the first and second outer legs 106, 108 are joined in a multi-step lap joint arrangement with plates the upper and lower yokes 102, 104 in a manner similar to the joining of the central yoke 110 to the upper and lower yokes 102, 104, described above. Such joining of the outer legs 106, 108 is described in U.S. Patent No. 7,877,861 B2, the content of which is hereby incorporated by reference into this specification.
- [0028] In the embodiment, each arc-shaped notch 122, 124 is a continuous cut-out defined by a continuous arc between points 132 that intersect with the associated inner side 104a the yoke plate 116 (FIG. 3). The size of the arc or radius in the plates 128 of the central leg 110 and the mating arc or radius of the plates 114, 116 in the upper and lower yokes 102, 104, respectively, is selected based on the width of the steel plates. Core steel scrap is reduced by using the radius or arc cut into the upper and lower yokes, as compared to the V-notch used in the prior art configuration of FIG. 1.
- [0029] The foregoing preferred embodiments have been shown and described for the purposes of illustrating the structural and functional principles of the present

invention, as well as illustrating the methods of employing the preferred embodiments and are subject to change without departing from such principles. Therefore, this invention includes all modifications encompassed within the spirit of the following claims.

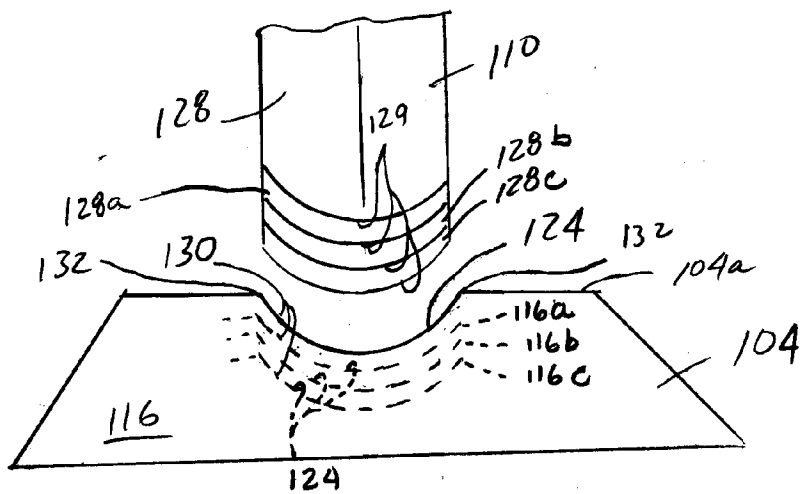
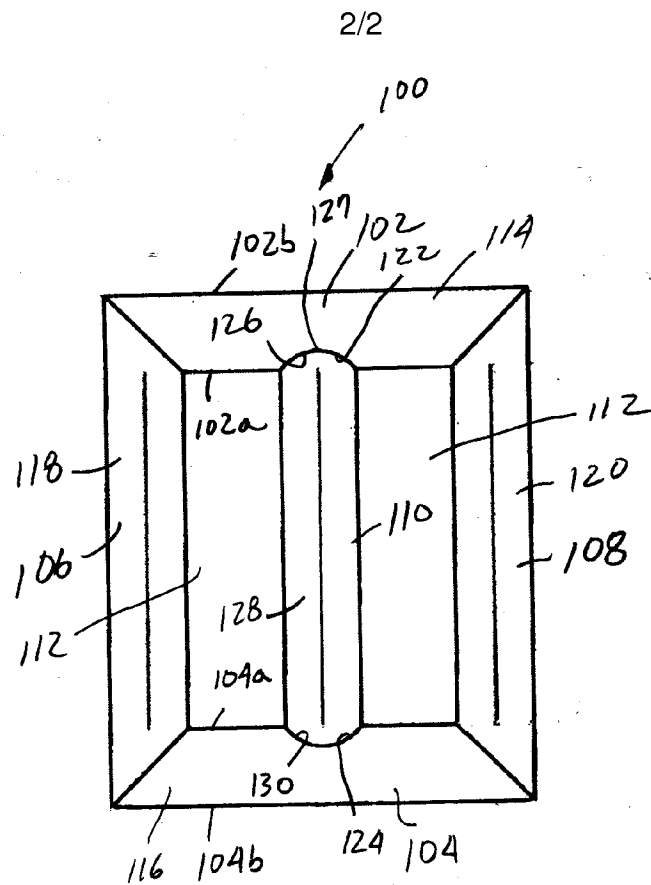
What is claimed is:

1. A transformer core comprising:  
a plurality of first and second outer leg plates;  
a plurality of inner leg plates, each having opposing, arc-shaped ends; and  
a plurality of upper yoke plates and a plurality of lower yoke plates, each of the upper and lower yoke plates having an outer side and an inner side with an arc-shaped notch formed in the inner side,  
wherein the inner leg plates, the upper and lower yoke plates, and the first and second outer leg plates are joined to form first and second outer legs from the first and second outer leg plates, respectively; an upper yoke and a lower yoke from the upper and lower yoke plates, respectively; and a central leg from the inner leg plates, with each arc-shaped end of the inner leg plates being joined with an associated arc-shaped notch of each of the upper and lower yoke plates.
2. The core of claim 1, wherein each of the plurality of first and second outer leg plates, the plurality of inner leg plates, and the plurality of upper and lower yoke plates, are in stacked relation.
3. The core of claim 2, wherein the arc-shaped ends are joined with the arc-shaped notches so as to be in a multi-step, lap joint arrangement.
4. The core of claim 1, wherein the first and second outer legs are joined to the upper and lower yokes to define a generally rectangular shape, with the central leg disposed between the upper and lower yokes, generally centrally between the first and second outer legs.
5. The core of claim 1, wherein each of the arc-shaped notches of the upper and lower yoke plates is a continuous cut-out defined by a continuous arc between points that intersect with the associated inner side of the associated yoke plate.
6. The core of claim 5, wherein each the arc-shaped notch is concave and the arc-shaped end that is joined therewith is convex.

7. A method of making a core for a transformer, the method comprising:  
providing a plurality of first and second outer leg plates;  
providing a plurality of inner leg plates, each having opposing, arc-shaped ends;  
providing a plurality of upper yoke plates and a plurality of lower yoke plates, each of the upper and lower yoke plates having an outer side and an inner side with an arc-shaped notch formed in the inner side; and  
joining the inner leg plates, the upper and lower yoke plates and the first and second outer leg plates to form first and second outer legs from the first and second outer leg plates, respectively; an upper yoke and a lower yoke from the upper and lower yoke plates, respectively; and a central leg from the inner leg plates, with each arc-shaped end of the inner leg plates being joined with an associated arc-shaped notch of each of the upper and lower yoke plates.
8. The method of claim 7, wherein the step of providing the plurality of first and second outer leg plates, the plurality of inner leg plates, and the plurality of upper and lower yoke plates, provides each plurality of plates in stacked relation.
9. The method of claim 8, wherein the joining step includes joining the plates in a multi-step, lap joint arrangement.
10. The method of claim 7, wherein the joining step includes joining first and second outer legs to the upper and lower yokes to define a generally rectangular shape, with the central leg disposed between the upper and lower yokes, generally centrally between the first and second outer legs.
11. The method of claim 7, wherein the step of providing the upper and lower yoke plates with arc-shaped notches, provides a continuous cut-out defined by a continuous arc between points that intersect with the associated inner side of the associated yoke plate.
12. The method of claim 11, wherein each the arc-shaped notch is concave and the arc-shaped end that is joined therewith is convex.



**Fig. 1** PRIOR ART



# INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2012/041195

A. CLASSIFICATION OF SUBJECT MATTER  
INV. H01F27/245 H01F41/02  
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                        | Relevant to claim No. |
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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# INTERNATIONAL SEARCH REPORT

International application No

PCT/US2012/041195

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                  | Relevant to claim No. |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
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Information on patent family members

International application No

PCT/US2012/041195

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