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2,889,525

THREE-PHASE CORE FOR TRANSFORMERS

Filed Dec. 13, 1954

2 Sheets-Sheet 1

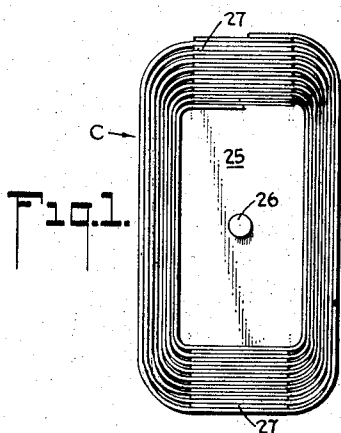


Fig. 1.

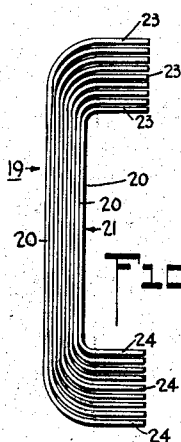


Fig. 3.

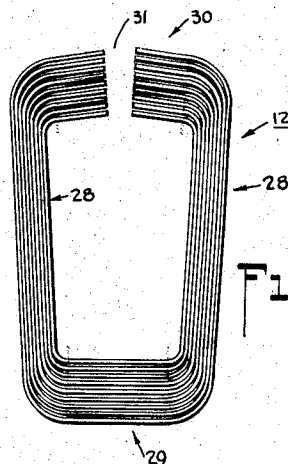


Fig. 2.

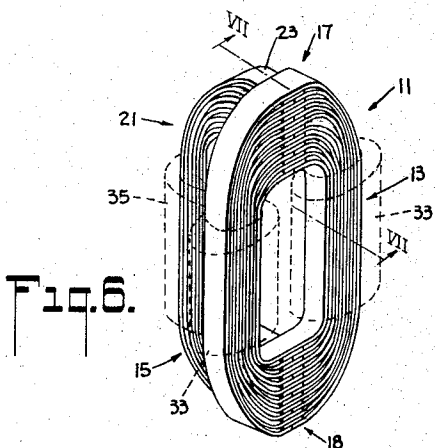


Fig. 6.

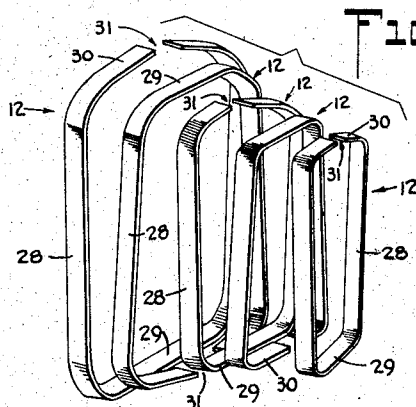


Fig. 4.

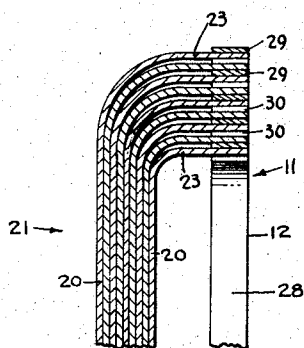


Fig. 7.

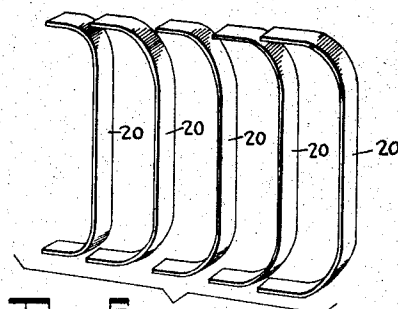


Fig. 5.

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2 Sheets-Sheet 2

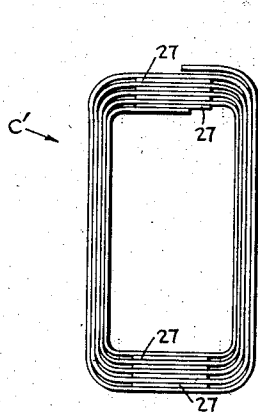


Fig. 8.

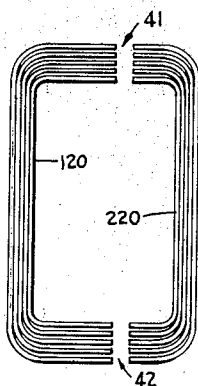


Fig. 9.

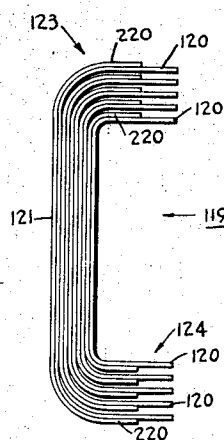


Fig. 10.

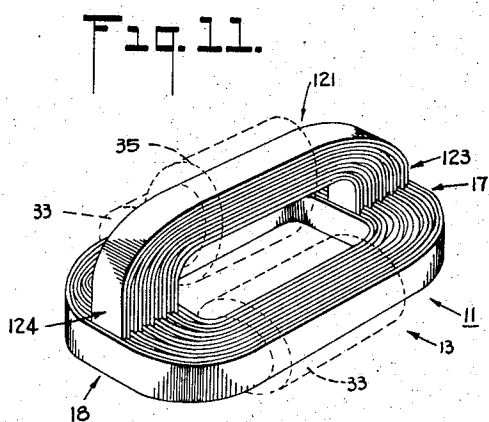


Fig. 11.

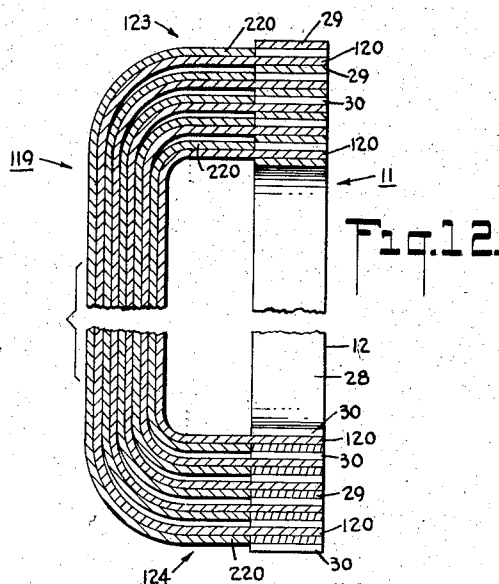


Fig. 12.

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THREE-PHASE CORE FOR TRANSFORMERS

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11 Claims. (Cl. 336—215)

This invention relates to magnetic cores, and particularly to three-phase magnetic cores, adapted for use in induction apparatus such as transformers, and to the method of making the same.

The invention particularly relates to the formation of three-phase core structures from strip-like magnetic metallic ribbon, preferably of the type in which the grain of the metal is oriented in the direction of magnetic flux, and provides new and novel improvements in three-phase transformer cores.

There have been numerous attempts to employ magnetic strip material in the formation of three-phase magnetic cores, and various forms and shapes of connecting yoke portions have been employed for interconnecting the winding leg portions of such cores. This invention is particularly directed to such transformer cores which includes substantially T-shaped yoke portions. In previously proposed constructions difficulties of assembly particularly in the associating of the phase windings with the respective windings legs have been encountered, and, although attempts have been made to overcome these difficulties of assembly, such attempts have resulted in impairing the efficiency and desirability of operation of the core structures.

Thus it has heretofore been contemplated that a continuous coil of strip material might be employed to provide two of the winding legs with a laminated third leg associated therewith. The employment of such a continuous wound coil has presented the difficulty of requiring the unwinding of the coil and the insertion of the free end thereof successively through the windows of the phase windings, continuing the rewinding until the previously wound coil has been completely inserted into the phase windings. To obviate the difficulty of this type of situation it has been proposed in some instances to sever the respective winding legs in order to provide for the removal of a yoke portion, permitting the simple mounting of the phase windings upon the winding legs, followed by the replacement of the severed yoke portions. This procedure has resulted in unsatisfactory performance because of the multiplicity of butt joints employed in reassociating the severed yoke portion with the winding leg portions.

Other types of solutions of this problem have been suggested, as for example a multiplicity of individual bundles of laminations have been associated together. The resultant structure has been faced with operational difficulties similar to those encountered in the severed-leg type of construction mentioned above, necessitating an excessive plurality of joints between the associated parts. Such excess of jointing is primarily inefficient in producing undesirable sound level characteristics, and by unsatisfactorily increasing magnetic losses, a condition inherent in jointing magnetic material.

The present invention is primarily directed to a three-phase core for transformers formed of a multiplicity of lamination layers of magnetic strip material which provides a maximum facility of associating phase windings

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with the winding legs of the core while reducing to a minimum the hitherto unsatisfactory plurality of joints among the respective lamination layers.

In particular this invention contemplates the production of a three-phase transformer core in which a series of substantially rectangular or quadrilateral lamination layers are nested together to provide a substantially rectangular stack including two winding legs and connecting yoke portions, and a third leg is provided by associating a substantially U-shaped bundle of nested lamination layers including a winding leg portion and upper and lower yoke portions with the substantially rectangular stack. In further particular the respective substantially rectangular lamination layers are independent each of the other and are substantially continuous, being interrupted along one of the connecting yoke portions to provide for access of phase windings to the winding leg portions, and in the preferred embodiment the interrupted yoke portions are alternately disposed at opposite ends of the nested stack ultimately formed in the fabrication of the core.

The principal object of the present invention is to provide a new and novel three-phase core for transformers.

A further object of the invention is to provide a new and novel method of producing three-phase cores for transformers.

A further object of the invention is to provide such a three-phase core which includes a substantially rectangular stack of independent quadrilateral lamination layers, one of the sides of each of the layers being interrupted for access, and the remainder of each of the layers being continuous and uninterrupted.

A further object of the invention is to provide such a transformer core in which the respective interrupted sides of successive said quadrilateral lamination layers are alternately disposed at opposite ends of the substantially rectangular stack.

A further object of the invention is to provide such a transformer core including a rectangular stack of quadrilateral lamination layers in which a third winding leg is provided by an associated U-shaped bundle of lamination layers, at least part of the lamination layers of the U-shaped bundle being interleaved between adjacent quadrilateral lamination layers.

A further object of the invention is to provide a method of fabricating a three-phase core for transformers which includes the steps of nesting a series of quadrilateral lamination layers to form a substantially rectangular stack, and associating a U-shaped bundle of lamination layers therewith to provide three substantially parallel winding legs for receiving phase windings of transformers.

A further object of the invention is to generally improve the design, construction and efficiency of three-phase cores for transformers; and

A further object of the invention is to generally improve the efficiency and facility in methods of making three-phase transformers and the cores for same.

The means by which the foregoing and other objects of the present invention are accomplished and the manner of their accomplishment will be readily understood from the following specification upon reference to the accompanying drawings, in which:

Fig. 1 is a face view of a substantially rectangular coil of magnetic strip material.

Fig. 2 is a face view of a coil like the coil of Fig. 1 with one of the short sides divided as by cutting to provide a nest of substantially quadrilateral lamination layers.

Fig. 3 is a face view of a half coil formed as by cutting through both of the sides of a coil like that of

Fig. 1 to provide one form of U-shaped bundle of lamination layers.

Fig. 4 is an exploded perspective view of part of the quadrilateral lamination layers as of Fig. 2, illustrating the preferred rearrangement and association of same during the assembly of a rectangular stack of nested laminations.

Fig. 5 is an exploded perspective view of part of the lamination layers as from the U-shaped bundle of Fig. 3.

Fig. 6 is a perspective view of the preferred embodiment of three-phase core for transformers in accordance with the present invention, with phase windings being indicated in dotted lines.

Fig. 7 is a fragmentary sectional view on an enlarged scale taken as on the line VII—VII of Fig. 6.

Fig. 8 is a face view of a coil similar to the coil of Fig. 1, but including a lesser number of turns.

Fig. 9 is a face view of the coil of Fig. 8 with the short sides thereof parted along a line parallel to but offset from the longitudinal center line of the coil to provide two substantially U-shaped bundles of lamination layers.

Fig. 10 is a face view of a modified U-shaped bundle of lamination layers formed by alternately stacking the lamination layers of the bundles of Fig. 9.

Fig. 11 is a perspective view of a three-phase core for transformers embodying the modified third leg of Fig. 10; and

Fig. 12 is a fragmentary sectional view on an enlarged scale taken as along a plane longitudinally bisecting the third leg of the core of Fig. 11, and bisecting the yoke joints.

Referring now to the drawings in which the various parts are indicated by numerals, it will be seen, particularly from Figs. 6 and 11, that the present invention relates to a three-phase T-core structure. In each of the alternative forms illustrated in the drawings a substantially rectangular stack 11 of nested rectangular and independent lamination layers 12 is employed, providing parallel winding leg portions 13, 15, and yoke portions 17, 18.

In the form of the structure illustrated in Fig. 6 a substantially U-shaped bundle 19 of independent lamination layers 20 is associated with stack 11, and when so associated provides a third or middle winding leg portion 21, and connecting yoke portions 23, 24.

Preferably and in order to facilitate the preparation of lamination layers 12 suitable magnetic strip material is withdrawn from a source of supply (not shown) and engaged as upon a mandrel 25, the mandrel 25 being rotated and forming of the strip material a continuous coil C of generally rectangular shape. For convenience it is preferred that the mandrel be rotatably supported as upon a suitable shaft 26. During the rotation of the mandrel in the formation of coil C suitable spacers 27 are interposed between the short sides of the successive layers of the strip material so as to provide, upon completion of the coil, spacings between the respective adjacent layers at the short sides of the coil. After a suitable length of the magnetic material has been wound into the coil, the coil may be subjected to strain relieving annealing.

A coil C is cut through a common short side of each of its turns as shown in Fig. 2 substantially at the center of the severed short sides. Such parting of the turns of coil C creates a nest of substantially rectangular independent lamination layers 12, each having opposite elongated leg portions 28, an uninterrupted short side 29, and a severed short side 30, having a gap 31.

The rectangular layers 12 are preferably unstacked from the arrangement shown in Fig. 2 and are successively introduced to the phase windings 33 shown in dotted lines in Fig. 6, the gaps 31 of the severed sides 30 being spread, such spread being within the elastic limits of the magnetic strip, and the separated parts of

the severed short sides 30 are inserted through the windows of the phase windings, and upon completion of such insertion are moved into butt jointed relationship closing the gap 31 and restoring the successive layers 12 to substantially rectangular condition.

It will be observed that in the preferred embodiment illustrated the successive layers 12 are respectively turned end for end relative to the adjacent inserted layers so that the severed portion 30 and its closed gap 31 of a first layer 12 are positioned in one yoke portion of the assembled stack 11, and portion 30 and butt jointed gap 31 of the next adjacent layer 12 is positioned in the opposite yoke portion of stack 11. Such alternate positioning of rectangular layers 12 is illustrated in Fig. 4 typifying the assembly relationship of the rectangular layers prior to introduction to the phase windings. A similar coil C is severed through both of the opposite short sides substantially along the center line of the short sides to produce a bundle 19 of substantially U-shaped lamination layers 20. The lamination layers 20 of bundle 19 are successively threaded through the window of a third phase winding 35 to position winding leg 21 in relationship to the phase winding 35, with yoke portions 23, 24 projecting substantially at right angles thereto and being of substantially uniform length. The third leg yoke portions 23, 24 are respectively interleaved between adjacent lamination layers of yoke portions 17, 18 of stack 11, and the third leg yoke portions are of a length to extend the entire width of the strip material of the respective rectangular layers 12.

It thus will be seen that in the completed core, as illustrated in Fig. 6, half of the lamination layers in yoke portion 17 are uninterrupted portions 29, and the remaining half of the lamination layers in yoke portion 17 are severed portions 30, each provided with a butt joint closing its gap 31. In each instance the butt jointed portions of the lamination layer sides 30 are lapped adjacent the butt joint and on their opposite faces by the interleaved yoke portions 23 of lamination layers 20.

It will further be observed that a similar condition obtains in yoke portion 18 in which each of the lamination layers 12 which is butt jointed in yoke portion 17 is continuous through yoke portion 18, and the remaining lamination layers 12, continuous through yoke portion 17, are respectively butt jointed in yoke portion 18 and the butt joints lapped by third leg yoke portions 24.

In the modified form illustrated in Fig. 11, as stated, a stack 11 of substantially rectangular lamination layers 12 is likewise employed, the principal modification lying in the formation of the U-shaped bundle from which the third leg of the core is formed. In this modification a separate coil C' is formed as by winding a suitable length of the magnetic strip material upon a mandrel 25, the winding being continued to produce a coil preferably having half the number of turns formed in coil C. During the winding, as in the winding of coil C, suitable spacers 27 are successively inserted between the adjacent short sides of the layers of coil C'.

The opposite short sides of coil C' are severed as at 41, 42, the respective cuts being formed along a line offset from and parallel to the longitudinal center line of coil C'. This severing of coil C' produces a U-shaped bundle of major lamination layers 120, and a second bundle of lesser lamination layers 220. Each of the lamination layers 120, 220 includes an elongated leg portion and yoke portions bent substantially at right angles to the leg portions, the yoke portions of laminations 120 being of a length exceeding the length of the yoke portions of laminations 220 by an amount substantially equal to the width of the strip material from which the lamination layers are formed.

U-shaped layers 120, 220 are unstacked from the respective bundles formed by the severing of coil C' and are reassembled into a substantially U-shaped bundle 119 in which the respective lamination layers 120, 220 are

alternated, as best shown in Fig. 10. The bundle 119 includes a winding leg portion 121 formed of the layers 120, 220, and yoke portions 123, 124 formed of the yoke portions of the respective layers 120, 220, each of the yoke portions 123, 124 including alternate short and long layer portions.

The respective layers of bundle 119 are threaded through the window of a phase winding 35, and are then associated with the lamination layers of a stack 11. The elongated yoke portions of layers 120 are interleaved between adjacent lamination layers 12 of stack 11, and the square ends of the shorter yoke portions of laminations 220 are each abutted against an edge of a lapped lamination layer 12. It thus will be seen that the bulk or thickness of the joint formed in the T-shaped yoke portion of this alternative embodiment of the core is reduced, enabling a space saving, while preserving through the present arrangement a highly satisfactory jointing between the respective parallel paths for flux flow.

It will be understood that while rectangular lamination layers 12 are preferably and most conveniently formed in the manner described by severing a continuous coil of magnetic strip material, they may be formed otherwise, as for example by successively bending individual lengths of strip material into substantially rectangular form having opposite leg portions, a continuous short side, and an opposite short side including a gap.

When the core is associated with the phase windings, the completed assembly may be mounted in a suitable tank-like container, not shown.

The term "lamination layer" has been used since one, or more than one, turn or lamination of strip material may be included therein.

I claim:

1. In a three-phase core structure for transformers having three winding legs arranged in parallel relation, in combination a plurality of independent, substantially rectangularly shaped lamination layers of magnetic strip material; each said layer including opposite leg portions and opposite yoke portions, one said yoke portion being uninterrupted and the other said yoke portion being interrupted and comprising a pair of yoke ends extending substantially to the transverse midline of said other yoke portion; said layers being nested to form a substantially rectangularly shaped stack of lamination layers, providing opposite winding legs and connecting yokes, the yoke ends of said other yoke portions of alternate said layers being positioned in one of said stack yokes and the remaining said yoke ends being positioned in the other of said stack yokes, the free ends of said yoke ends being abutted in said stack yokes to form butt joints in said layers alternately positioned at opposite ends of said stack; and a substantially U-shaped bundle of a like plurality of curved lamination layers of magnetic strip material, providing a winding leg and two yoke portions connected substantially at right angles to said bundle winding leg, said bundle yoke portions joining with said stack yokes to provide a T-core structure.

2. In a three-phase core structure for transformers having three winding legs arranged in parallel relation, in combination a plurality of independent, substantially rectangularly shaped lamination layers of magnetic strip material; each said layer including opposite leg portions and opposite yoke portions, one said yoke portion being uninterrupted and the other said yoke portion being interrupted and comprising a pair of yoke ends extending substantially to the transverse midline of said other yoke portion; said layers being nested to form a substantially rectangularly shaped stack of lamination layers, providing opposite winding legs and connecting yokes, the yoke ends of said other yoke portions of alternate said layers being positioned in one of said stack yokes and the remaining said yoke ends being positioned in the other of said stack yokes, the free ends of said yoke ends being abutted in said stack yokes to form butt joints in said

layers alternately positioned at opposite ends of said stack; and a substantially U-shaped bundle of a like plurality of curved lamination layers of magnetic strip material, providing a winding leg and two yoke portions connected substantially at right angles to said bundle winding leg, said bundle yoke portions joining with said stack yokes to provide a T-core structure, each said yoke end but joint being lapped by the yoke portion of at least one of said bundle layers.

3. In a three-phase core structure for transformers having three winding legs arranged in parallel relation, in combination a plurality of independent, substantially rectangularly shaped lamination layers of magnetic strip material; each said layer including opposite leg portions and opposite yoke portions, one said yoke portion being uninterrupted and the other said yoke portion being interrupted and comprising a pair of yoke ends extending substantially to the transverse midline of said other yoke portion; said layers being nested to form a substantially rectangularly shaped stack of lamination layers, providing opposite winding legs and connecting yokes, the yoke ends of said other yoke portions of alternate said layers being positioned in one of said stack yokes and the remaining said yoke ends being positioned in the other of said stack yokes, the free ends of said yoke ends being abutted in said stack yokes to form butt joints in said layers alternately positioned at opposite ends of said stack; and a substantially U-shaped bundle of a like plurality of curved lamination layers of magnetic strip material providing a winding leg and two yoke portions connected substantially at right angles to said bundle winding leg, said bundle yoke portions joining with said stack yokes to provide a T-core structure, each said yoke end but joint being lapped by yoke portions of adjacent said bundle layers.

4. In a three-phase core structure for transformers having three winding legs arranged in parallel relation, in combination a plurality of independent, substantially rectangularly shaped lamination layers of magnetic strip material; each said layer including opposite leg portions and opposite yoke portions, one said yoke portion being uninterrupted and the other said yoke portion being interrupted and comprising a pair of yoke ends; said layers being nested to form a substantially rectangularly shaped stack of lamination layers, providing opposite winding legs and connecting yokes, the free ends of said yoke ends being abutted to form butt joints in said layers; and a substantially U-shaped bundle of a like plurality of curved lamination layers of magnetic strip material, providing a winding leg and two yoke portions connected substantially at right angles to said bundle winding leg, said bundle yoke portions joining with said stack yokes to provide a T-core structure, each said yoke end but joint being lapped by the yoke portion of at least one of said bundle layers.

5. In a three-phase core structure for transformers having three winding legs arranged in parallel relation, in combination a plurality of independent, substantially rectangularly shaped lamination layers of magnetic strip material; each said layer including opposite leg portions and opposite yoke portions, one said yoke portion being uninterrupted and the other said yoke portion being interrupted and comprising a pair of yoke ends; said layers being nested to form a substantially rectangularly shaped stack of lamination layers, providing opposite winding legs and connecting yokes, the yoke ends of said other yoke portions of alternate said layers being positioned in one of said stack yokes and the remaining said yoke ends being positioned in the other of said stack yokes, the free ends of said yoke ends being abutted in said stack yokes to form butt joints in said layers alternately positioned at opposite ends of said stack; and a substantially U-shaped bundle of a like plurality of curved lamination layers of magnetic strip material, pro-

viding a winding leg and two yoke portions connected substantially at right angles to said bundle winding leg, the ends of said bundle yoke portions respectively lapping with the layers of said stack yokes to provide a T-core structure.

6. In a three-phase core structure for transformers having three winding legs arranged in parallel relation, in combination a plurality of independent, substantially rectangularly shaped lamination layers of magnetic strip material; each said layer including opposite leg portions and opposite yoke portions, one said yoke portion being uninterrupted and the other said yoke portion being interrupted and comprising a pair of yoke ends extending substantially to the transverse midline of said other yoke portion; said layers being nested to form a substantially rectangularly shaped stack of lamination layers, providing opposite winding legs and connecting yokes, the yoke ends of said other yoke portions of alternate said layers being positioned in one of said stack yokes and the remaining said yoke ends being positioned in the other of said stack yokes, the free ends of said yoke ends being abutted in said stack yokes to form butt joints in said layers alternately positioned at opposite ends of said stack; and a like plurality of substantially U-shaped lamination layers of magnetic strip material, each including a leg portion and opposite yoke portions, said U-shaped layers being nested in a substantially U-shaped bundle, the yoke portions of alternate said U-shaped layers in said bundle being of a length exceeding the length of adjacent bundle layer yoke portions, said bundle providing a winding leg and connecting yokes including alternate projecting yoke portion ends, said projecting yoke portion ends being respectively lappingly interleaved between adjacent said stack layers, the ends of the remaining bundle layer yoke portions being abutted against edge portions of said stack layers, to join said bundle yokes with said stack yokes to provide a T-core structure, said yoke end butt joints being lapped by said projecting yoke portion ends.

7. In a three-phase core structure for transformers having three winding legs arranged in parallel relation, in combination a plurality of independent, substantially rectangularly shaped lamination layers of magnetic strip material; each said layer including opposite leg portions and opposite yoke portions, one said yoke portion being uninterrupted and the other said yoke portion being interrupted and comprising a pair of yoke ends; said layers being nested to form a substantially rectangularly shaped stack of lamination layers, providing opposite winding legs and connecting yokes, the free ends of said interrupted layer yoke portions of alternate said layers being positioned in one of said stack yokes and the remaining said yoke ends of interrupted yoke portions being positioned in the other of said stack yokes, the free ends of said yoke ends being abutted in said stack yokes to form butt joints in said layers alternately positioned at opposite ends of said stack; and a like plurality of substantially U-shaped lamination layers of magnetic strip material, each including a leg portion and opposite yoke portions, said U-shaped layers being nested in a substantially U-shaped bundle, the yoke portions of alternate said U-shaped layers in said bundle being of a length exceeding the length of adjacent bundle layer yoke portions, said bundle providing a winding leg and connecting yokes including alternate projecting yoke portion ends, said projecting yoke portion ends being respectively lappingly interleaved between adjacent said stack layers, the ends of the remaining bundle layer yoke portions being abutted against edge portions of said stack layers, to join said bundle yokes with said stack yokes to provide a T-core structure.

8. In a three-phase core structure for transformers having three winding legs arranged in parallel relation, in combination a plurality of independent, substantially rec-

tangularly shaped, discontinuous lamination layers of magnetic strip material, each layer comprising a pair of winding leg portions, an uninterrupted yoke portion connecting said winding leg portions and an interrupted yoke portion having free ends respectively connected to said leg portions, said layers being concentrically nested to form a substantially rectangularly shaped stack of lamination layers, providing opposite winding legs and connecting yokes, the free ends of each of said interrupted yoke portions being abutted to form butt joints in said layers, and a substantially U-shaped bundle of a like plurality of curved lamination layers of magnetic strip material, providing a winding leg and two yoke portions, the ends of said lamination layers of said U-shaped bundle being interleaved with said stack laminations at opposite said stack connecting yokes to form a T-core structure.

9. In a three-phase core structure for transformers having three winding legs arranged in parallel relation, in combination a plurality of independent, substantially rectangularly shaped, discontinuous lamination layers of magnetic strip material, each layer comprising a pair of winding leg portions, an uninterrupted yoke portion connecting said winding leg portions and an interrupted yoke portion having free ends respectively connected to said leg portions, said layers being concentrically nested to form a substantially rectangularly shaped stack of lamination layers, providing opposite winding legs and connecting yokes, the free ends of each of said interrupted yoke portions being abutted to form butt joints in said layers, and a substantially U-shaped bundle of a like plurality of curved lamination layers of magnetic strip material, providing a winding leg and two yoke portions, said lamination layers in said U-shaped bundle consisting of major lamination layers and lesser lamination layers, said major lamination layers being greater in length than said lesser lamination layers, the ends of said major lamination layers being interleaved with said stack lamination layers at opposite said stack connecting yokes and the ends of said lesser lamination layers abutting against edge portions of said stack layers, to form a T-core structure.

10. In a three-phase core structure for transformers having three winding legs arranged in parallel relation, in combination a plurality of independent, substantially rectangularly shaped, discontinuous lamination layers of magnetic strip material, each layer comprising a pair of winding leg portions, an uninterrupted yoke portion connecting said winding leg portions and an interrupted yoke portion having free ends respectively connected to said leg portions, said layers being concentrically nested to form a substantially rectangular stack of lamination layers, providing opposite winding legs and connecting yokes, the free ends of each of said interrupted yoke portions being abutted to form butt joints in said layers, said butt joints of successive said lamination layers being alternately positioned in opposite stack yokes, and a substantially U-shaped bundle of a plurality of curved lamination layers of magnetic strip material, providing a winding leg and two yoke portions, said lamination layers in said U-shaped bundle consisting of major lamination layers and lesser lamination layers, said major lamination layers being greater in length than said lesser lamination layers, the ends of said major lamination layers being interleaved with said stack lamination layers at opposite said stack connecting yokes and being in lapped relationship with adjacent said butt joints, the ends of said lesser lamination layers abutting against edge portions of said stack layers, to form a T-core structure.

11. In a three-phase core structure for transformers having three winding legs in parallel relation, in combination a plurality of nested substantially rectangularly shaped lamination layers of magnetic material providing a stack having winding legs and connecting yokes, each said

layer including a pair of winding leg portions, an interrupted yoke portion and an interrupted yoke portion, the ends of said layers in said interrupted yoke portions butting in said stack, and a bundle of a plurality of substantially U-shaped lamination layers, the free ends of said bundle layers jointing to said stack yoke portions. 5

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