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MAGNETIC CORES

Filed July 25, 1955

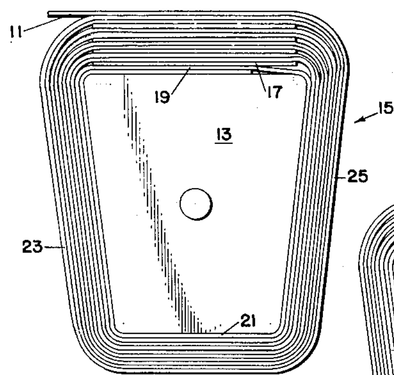

FIG. 1.

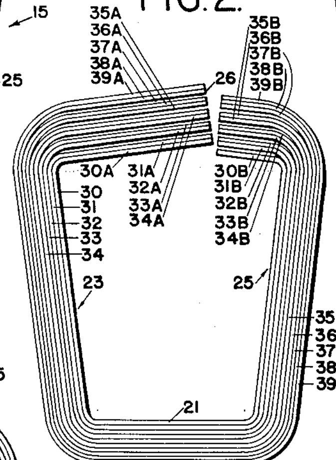

FIG. 2.

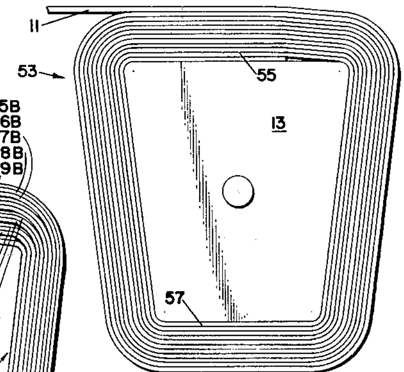

FIG. 4.

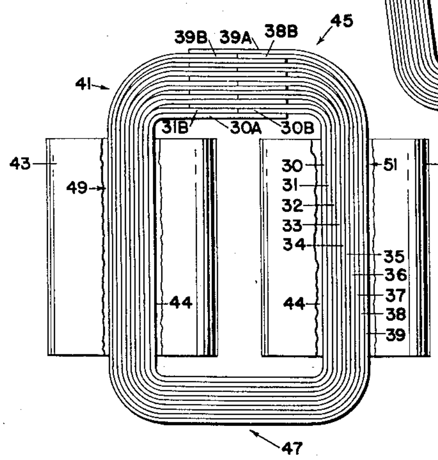

FIG. 3.

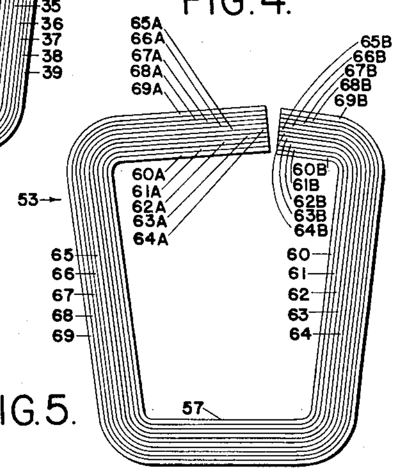

FIG. 5.

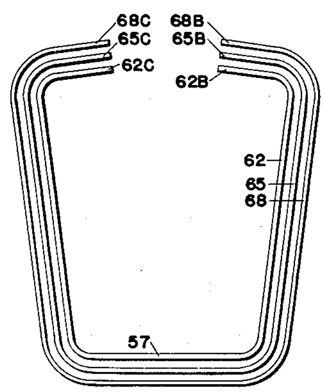

FIG. 6.

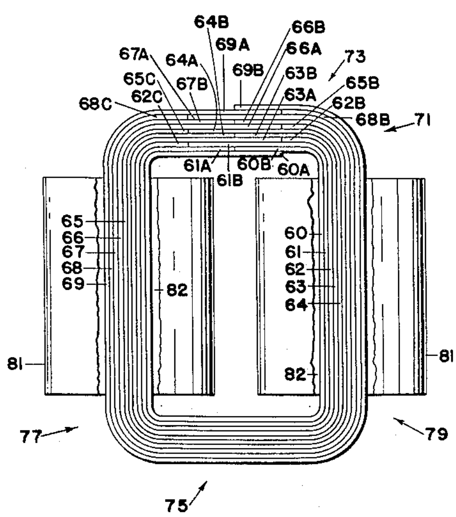

FIG. 7.

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2 Claims. (Cl. 336—217)

This invention relates to certain new and useful improvements in the method of manufacturing magnetic transformer cores and the product obtained therefrom.

It has been a well-known practice in the art of manufacturing magnetic transformers to wind the coil independently and subsequently either join a pre-formed core with the coil or build up a core around the coil. Since in the final form of the transformer the coil and the core both form closed loops linked with one another, rather than wind one about the legs of the other, it has been expedient to provide a break in the core whereby the core and the coil may be linked. The problem of subsequently joining the ends of the laminations or turns of the core in an efficient manner has heretofore been an ever-present problem in the field of transformer manufacturing. Heretofore, the individual lamination layers or turns of transformer cores have been joined by either the so-called butt joint method in which the ends of the lamination layers or turns are abutted or the so-called lap joint in which the ends of the laminations have been joined by lapping one end over the other. In the butt joint method the magnetizing current has been high due to the fact that the core has a high resistance at the joints. In the lap joint method an excessive build-up is created in the area of the joints since the layers are doubled in this area. This excessive build-up is undesirable since it creates a transformer which is unduly bulky. Additionally in this method there is a waste of material since the lapped portion of the joint does not add to the effective length of the core.

The present invention is directed towards providing a method of forming a transformer core and the product obtained therefrom in which the abovementioned problems encountered with the so-called butt joint and so-called lap joint are alleviated.

It is contemplated that a transformer core fabricated by the method of the present invention has an improved joint whereby a transformer constructed with said core will have the characteristics of now core loss. In such a transformer core the build-up in the joint area will be reduced and there will be a savings in core material over the lap-joint method.

Further it is contemplated that such a transformer core will be provided with a joint in which the ends of the individual lamination layers are lapped and one of said ends abutted with an adjacent layer, whereby a joint is provided having a build-up of one and a half times the thickness of the other legs of the core rather than twice the thickness as in the conventional lap joint.

Further it is contemplated that an alternate embodiment of the subject invention will be provided with a joint in which the ends of successive pairs of lamination layers are lapped, with one of said ends being abutted with an adjacent layer, and with a plurality of shortened lamination layers being respectively interposed between said successive pairs and abutted with a pair of ends thereof, whereby a joint is provided having the same thickness as the other legs of the core.

It is an object of the present invention to provide new and useful improvements in the method of manufacturing magnetic transformer cores.

It is a further object of the invention to provide such a method which includes the steps of winding magnetic

strip material on a trapezoidally-shaped mandrel to form a core winding, annealing said core winding in wound condition, cutting through the longer of the unequal legs of said core winding off center from the vertical center line of said longer leg, building a core by alternately reversing lamination layers from said core winding and forming a joint in which the ends of the individual lamination layers will be lapped and one of said ends abutted with an adjacent layer.

A further object of the present invention is to provide such a method of forming a transformer core which includes the additional steps of removing every third lamination layer of said core winding and cutting a segment therefrom, and interposing said third lamination layers between successive pairs of lapped lamination layers in said core, abutting ends of lapped layers, to close the gaps formed by the lapped laminations whereby a core is provided having uniform leg thickness.

A further object of the present invention is to provide a transformer core having a concentrically stacked series of lamination layers, each series comprising a pair of lapped lamination layers in which one end of each of said pair are in abutment.

A further object of the invention is to provide a transformer core having a concentrically stacked series of lamination layers; each said series comprising a pair of lamination layers, each having their ends overlapping, one end of each of said pair being in abutment; and having shortened lamination layers respectively interposed between said series, the ends of which being in abutment with the ends of said series.

A further object of the invention is to generally improve the design and construction of transformer cores and the method for making 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 front elevational view of a core winding of magnetic strip material for a transformer core, as illustrated on a mandrel upon which it has been wound.

FIG. 2 is a front elevational view of the core winding after annealing and severing.

FIG. 3 is a front elevational view of the completed core.

FIG. 4 is a front elevational view of a core winding of magnetic strip material for a transformer core of an alternate construction as illustrated on a mandrel upon which it has been wound.

FIG. 5 is a front elevational view of the core winding of FIG. 4 after annealing and severing.

FIG. 6 is a front elevational view of a stack of lamination layers removed from the severed core winding of FIG. 5, after having a segment cut therefrom.

FIG. 7 is a front elevational view of the completed transformer core of alternate construction.

Referring now to the drawings in which the various parts are indicated by numerals, ferrous strip material having suitable magnetic properties for use in transformer cores is first wound on a trapezoidal mandrel to produce a continuous coil of strip material. Thus as illustrated in FIG. 1, strip material **11** introduced to the trapezoidal mandrel **13**, from a source of supply not shown, is secured to the mandrel in any desired manner, and the mandrel is rotated, in the embodiment illustrated, in a clockwise direction to produce core winding **15**. During the winding operation independent spacers **17** are respectively inserted between successive pairs of lamination layers in the longer leg **19** of the unequal legs **19**, **21** of core winding **15**. The term "lamination layers" is used herein to refer to the individual layers since one or more laminations of magnetic strip material may be included in each of said layers.

Spacers 17 are preferably of a thickness equal to the thickness of an individual lamination layer whereby the total build-up of thickness of the leg 19 will be equal to one and one-half times the thickness of the shorter leg 21 of the two unequal legs and similarly one and a half times the thickness of the two equal winding legs 23, 25 of core winding 15. As will be more apparent in the description of the formation of the final core, spacers 17 provide the necessary space factor as indicated at 26 between successive pairs of lamination layers in order to accommodate the free ends of the successive pairs of lamination layers and to insure the proper length thereof.

After the desired number of turns of lamination layers have been wound on the mandrel 13, which is governed by the particular transformer design required, the strip material 11 is severed from the core winding 15, which is then removed from the mandrel and bonded with suitable bonding straps, whereby the shape of the core winding as formed on the mandrel is substantially maintained.

Spacers 17 are removed from core winding 15 and the core winding placed in a suitable oven or other heating device where the core winding is annealed at the proper temperature to remove the stresses set up during the winding process, thereby improving the magnetic properties of the strip. Additionally the annealing sets the shape of the core winding 15 substantially as bound.

After core winding 15 has been annealed the longer leg 19 of the core is severed to produce discontinuous lamination layers, as illustrated in FIG. 2. The discontinuous lamination layers, beginning at the inner layer and continuing outwardly for convenience, are herein designated as at 30, 31, 32, 33, 34, 35, 36, 37, 38 and 39 respectively.

The severing of the longer leg 19 may be accomplished as by means of a band saw or other cutting means, the cut being made transversely through the material of the leg along a line laterally offset from the vertical center line of leg 19, as for example to the right of the center line of leg 19, as illustrated in FIG. 2. The amount of offset of the cutting line is determined by the desired amount of overlap of the individual lamination layers of the completed core. Also the amount of overlap desired in the completed core should be taken into consideration in determining the dimensions of trapezoidal mandrel 13. It will be understood that the amount of overlap of the individual lamination layers necessary to produce a substantially rectangular final core will equal the amount that the longer of the two unequal sides of mandrel 13 exceeds the shorter of the two unequal sides of the mandrel. It follows that the longer leg 19 of core winding 15 having been wound on mandrel 13, dimensioned as hereinabove described, will exceed the shorter leg 21 by an amount equal to said overlap of individual lamination layers in the final core. Having selected the desired amount of said overlap of individual lamination layers, which will be hereinafter referred to as overlap length, the severing of leg 19 is preferably made along a line offset from the center line of leg 19 by an amount equal to said overlap length. Referring to FIG. 2, the free ends of the discontinuous lamination layers thus formed are herein respectively designated with the suffixes A and B, the longer free ends formed from leg 19 being designated with the suffix A and the shorter free ends with the suffix B. Thus the longer free ends of lamination layers 30, 31, 32, 33, 34, etc., are designated 30A, 31A, 32A, 33A, 34A, etc., and the shorter free ends 30B, 31B, 32B, 34B, etc.

The lamination layers of severed core winding 15 are then removed from the core winding and restacked to form completed core 41, as best illustrated in FIG. 3. In assembling the completed core, first the innermost lamination layer 30 may be linked with a pair of coils 43 by spreading the free ends 30A, 30B, inserting said ends through the windows 44 of coils 43 and subsequently joining the ends by overlapping free end 30B on free end 30A, said free ends preferably overlapping by an amount equal to said overlap length. It will be understood that free end 30B terminates substantially at the vertical center line of the upper leg 45 of core 41 and free end 30A terminates at a point offset to the right of said center line by an amount equal to said overlap amount. Next the lamination layer 31 may be similarly linked with core 43 and concentrically stacked over layer 30, but before insertion through the windows of coils 43 layer 31 is reversed, that is rotated 180° relative to layer 30. After linking with coils 43 the free ends of layer 31 are joined by overlapping free end 31A on free end 31B and the distal end of free end 31B is abutted with the distal end of free end 30B. It will be understood that by rotating layer 31 with respect to layer 30, free end 31A will terminate at a point which is offset to the left of the vertical center line of leg 45 and by an amount substantially equal to said overlap amount.

Layer 32 is then linked with coils 43 and concentrically stacked over layer 31 with free ends 32A, 32B joined in a manner similar to the joining of the free ends of layer 30. Thus free end 32B is overlapped on free end 32A, which terminates at a point which is offset to the right of the vertical center line of leg 45 by an amount substantially equal to said overlap amount. Next, lamination layer 33 is linked with coils 43 and concentrically stacked over layer 32, but is rotated 180° relative to layer 32 before insertion through the windows of coils 43. After linking, the free ends of layer 33 are joined similar to the joining of layer 31. Thus free end 33A is overlapped on free end 33B and the distal end of free end 33B abutted with the distal end of free end 32B.

In a like manner the remainder of the core is assembled by successively linking the layers 34, 35, 36, 37, 38 and 39 with coils 43 and joining the free ends. Thus the odd numbered layers 35, 37, and 39 are rotated 180° relative to the even numbered layers 34, 36 and 38, the free ends 34B, 35A, 36B, 37A, 38B, 39A are respectively overlapped on free ends 34A, 35B, 36A, 37B, 38A, 39B, and the distal ends of free ends 35B, 37B, 39B respectively abutted with the distal ends of free ends 34B, 36B, 38B whereby a joint is formed in which free ends 35A, 37A and 39A terminate along a line which is offset to the left of the center line of leg 45, free ends 34A, 36A and 38A terminate along a line which is offset to the right of the center line of leg 45 and free ends 34B, 35B, 36B, 37B, 38B and 39B terminate along a line which is substantially co-extensive with the center line of leg 45.

It will be understood from the foregoing description that a core 41 formed in accordance with the herein described process will have a build-up or thickness in leg 45, wherein the joint is formed, which will equal one and one-half times the thickness of the opposite leg 47 or the side legs 49, 51. In addition, it is apparent that such a core is formed in which there is a concentrically stacked series of lamination layers, each having their free ends overlapped and the distal end of a free end of one of said pair in abutment with the distal end of a free end of the other of said pair.

It will be apparent that a pair of cores may be formed by winding two core windings as described for the formation of core winding 15, severing said pair of core windings through the longer of their unequal legs, one core being severed off center to one side of the center line by the same amount and combining the lamination layers of the core windings thus several in a manner similar to the assembly of core 41. Thus the even numbered turns from one of said core windings may be combined with the odd numbered turns from the other of said core windings to form one core and the odd numbered turns from said one of said core windings may be combined with the even numbered turns from said other of said core windings to form another core. It is obvious that the alternate layers do not have to be rotated 180° as in the formation of core 45 since with the use of two core windings respectively severed at oppositely offset points from the center line the same effect is obtained.

An alternate method of forming a core in accordance with the present invention includes first winding suitable ferrous strip material on a trapezoidal mandrel to produce a continuous coil of strip material. Thus, as illustrated in FIG. 4, strip material **11** introduced to a trapezoidal mandrel **13** from a source of supply, not shown, is secured to the mandrel in any desired manner, and the mandrel is rotated, in the embodiment illustrated, in a clockwise direction to produce core winding **53**. The formation of core winding **53** is similar to the method heretofore described for the formation of core winding **15** except the spacers **17** are omitted in the processing of core winding **53**. Similar to the processing of core winding **15**, core winding **53** is removed from the mandrel **13**, bonded with suitable bonding straps and annealed in an oven.

After annealing, the longer leg **55** of the two unequal legs **55**, **57** of core winding **53** is severed to produce discontinuous lamination layers as illustrated in FIG. 5. The discontinuous lamination layers, beginning at the inner layer and continuing outwardly, will be herein designated as at **60**, **61**, **62**, **63**, **64**, **65**, **66**, **67**, **68** and **69** respectively.

Similar to the severing of core winding **15**, the severing of leg **55** is made transversely through the material of the leg along a line offset from the center line of leg **55**, as for example to the right of the center line of leg **55**, as illustrated in FIG. 5. The selection of the amount that the cutting line is offset will, just as heretofore described for the method of forming core winding **15**, be dependent upon the desired overlap amount in the final core. Similarly the dimensions of the trapezoidal mandrel will be dependent thereon. The free ends of the discontinuous lamination layers formed by severing leg **55** as herein above described will herein be designated by the suffixes A and B, the longer free end being designated with the suffix A and the shorter free end with the suffix B. Thus the longer free ends of lamination layers **60**, **61**, **62**, **63**, **64**, etc., are designated **60A**, **62A**, **63A**, **64A**, etc., and the shorter free ends **60B**, **61B**, **62B** **63B**, **64B**, etc.

After severing, every third lamination layer is removed from severed core winding **53** and may be restacked to provide a stack of third laminations **62**, **65**, **68**. A segment of each of the longer free ends **62A**, **65A**, **68A** of layers **62**, **65**, **68** is then cut off, as by means of a band saw or other cutting means, leaving free ends **62C**, **65C** and **68C**. Preferably the length of said segment is equal to said overlap length whereby free ends **62C**, **65C** and **68C** will be equal to free ends **52B**, **65B** and **68B** and the gap between the distal ends of said free ends will be equal to twice said overlap length.

The lamination layers **60**, **61**, **63**, **64**, **66**, **67**, **69**, remaining after removal of every third lamination layer, and said third lamination layers **62**, **65**, **68**, each having a segment removed as above described, are assembled together to form a final core **71** of generally rectangular shape. In general the method of assembly comprises assembling lamination layers **60**, **61**, **63**, **64**, **66**, **67**, **69** in a manner similar to the formation of core **41** and including additionally the step of respectively interposing lamination layers **62**, **65**, **68** between successive pairs of lamination layers **60**, **61**, **63**, **64**, **67**, **69** to fill the gaps formed by the joints thereof whereby a core is formed having legs **73**, **75**, **77**, **79**, of substantially equal thickness.

Thus in assembling core **71** first the innermost lamination layer **60** may be linked with a pair of coils **81** and the ends of layer **60** joined by overlapping free end **60B** on free end **60A** by an amount equal to said overlap length. It will be understood that free end **60B** terminates substantially at the mid-point of the upper leg **73** and core **71** and free end **60A** terminates at a point offset to the right of said mid-point by an amount equal to said overlap amount. Next lamination layer **61** may be similarly linked with coils **81** and concentrically stacked over layer **60**, but before insertion through the windows **82** of coils **81** layer **61** is rotated 180° relative to layer **60**. After linking with coils **81** the free ends of layer **61** are joined by overlapping free end **61A** on free end **61B** and abutting the distal end of free end **61B** with the distal end of free end **60B**. It will be understood that by rotating layer **61** with respect to layer **60** free end **61A** will terminate at a point which is offset to the left of the midpoint of leg **45** and by an amount substantially equal to said overlap amount.

Layer **62** is then linked with coils **81** and concentrically stacked over layer **61** with the distal end of free end **62C** abutting the distal end of free end **61A**.

Next layer **63** is linked with coils **81** and concentrically stacked over layer **62** with the distal end of free end **63A** abutting the distal end of free end **62B** and free end **63B** overlapping free end **63A**. Layer **64** is rotated 180° relative to layer **63**, then linked with coils **81**, and concentrically stacked over layer **63** with the distal end of free end **64B** abutting the distal end of free end **63B** and free end **64A** overlapping free end **64B**.

Layer **65** is then linked with coils **81** and stacked over layer **64** with the distal end of free end **65C** abutting the distal end of free end **64A**.

In a like manner the remainder of the core is assembled by successively linking the layers **66**, **67**, **68**, and **69** with coils **81** and joining the free ends of the layers. Thus the free ends **66B**, **67B**, **69B** are respectively overlapped on free ends **66A**, **67A**, **69A**, the distal end of free ends **66B**, **68C**, **68B** respectively abuted with the distal end of free ends **67B**, **67A**, **69A**, whereby a joint is formed in which free ends **61A**, **64A**, **67A** respectively abut free ends **62C**, **65C**, **68C** along a line which is offset to the left of the center line of leg **73** by an amount equal to said overlap length, free ends **63A**, **66A**, **69A** respectively abut free ends **62B**, **65B**, **68B** along a line which is offset to the right of said center line by a similar amount, and free ends **60B**, **63B**, **66B** respectively abut free ends **61B**, **64B** and **67B** along a line substantially co-extensive with the center line of leg **73**.

It will be apparent that a pair of cores similar to core **71** may be formed from a pair of core windings similar to core windings **53** by severing one core winding offset to the left and the other offset to the right which will give the same result as reversing or rotating lamination layers from a single core winding.

Thus it is apparent from the foregoing description that a core or cores fabricated in accordance with the alternate method will comprise a concentrically stacked series of lamination layers, each series comprising a pair of lamination layers, each having their ends overlapping and each of said pair having one of their ends in abutment with one of the ends of the other of said pair and shortened lamination layers respectively interposed between said series and the ends of which are in abutment with the ends of said series, providing a core of uniform cross-sectional thickness throughout its length.

I claim:

1. In a transformer core comprising a multiplicity of concentrically stacked discontinuous single turn lamination layers, each said layer including a discontinuous upper leg, a lower leg opposite to said upper leg, a pair of sides respectively joining said legs; said layers including a plurality of pairs of lamination layers, the upper leg of each layer of each pair including a long leg portion and a short leg portion, the free ends of said leg portions being overlapped, the length of the long leg portions respectively exceeding the length of the short leg portions by the amount of overlap of the free ends, said layers of each pair being positioned with the free end of the long

leg portion of one disposed intermediate the vertical center line of the core and one of said sides and the free end of the long leg portion of the other disposed intermediate said center line and the other of said sides and the free ends of the short leg portions abutted substantially on said center line; a similar plurality of shortened less than single turn lamination layers, respectively interposed between adjacent said pairs of layers, each said shortened layer upper leg including a pair of short leg portions having a length similar to the length of the first mentioned short leg portions, the free ends of the shortened layer leg portions respectively abutting the upper free end of one said pair of layers and the lower free end of the next adjacent pair of layers, respectively intermediate said center line and said sides, whereby to provide a core of substantially uniform cross-section throughout the length of said nested layers.

2. In a transformer, a core comprising a multiplicity of concentrically stacked discontinuous single turn lamination layers, each said layer including a discontinuous upper leg, a lower leg opposite to said upper leg, a pair of sides respectively joining said legs; said upper legs and lower legs of said nested layers respectively comprising the core yokes, and said nested layer sides respectively comprising the sides of said core, said layers including a plurality of pairs of lamination layers, the upper leg of each layer of each pair including a long leg portion and a short leg portion, the free ends of said leg portions being overlapped, the length of the long leg portions respectively exceeding the length of the short leg portions by the amount of overlap of the free ends, said layers of each pair being positioned with the free end of the long leg portion of one disposed intermediate the vertical center line of the core and one of said sides and the free end of the long leg portion of the other disposed intermediate said center line and the other of said sides and the free ends of the short leg portions abutted substantially on said center line; a similar plurality of shortened less than single turn lamination layers, respectively interposed between adjacent said pairs of layers, each said shortened layer upper leg including a pair of short leg portions having a length similar to the length of the first mentioned short leg portions, the free ends of the shortened layer leg portions respectively abutting the upper free end of one said pair of layers and the lower free end of the next adjacent pair of layers respectively intermediate said center line and said sides, whereby to provide a core of substantially uniform cross-section throughout the length of said nested layers, and a transformer coil linked to at least one side of said core.

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