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METHOD OF MAKING POLYPHASE TRANSFORMERS

Original Filed April 12, 1954 3 Sheets-Sheet 1

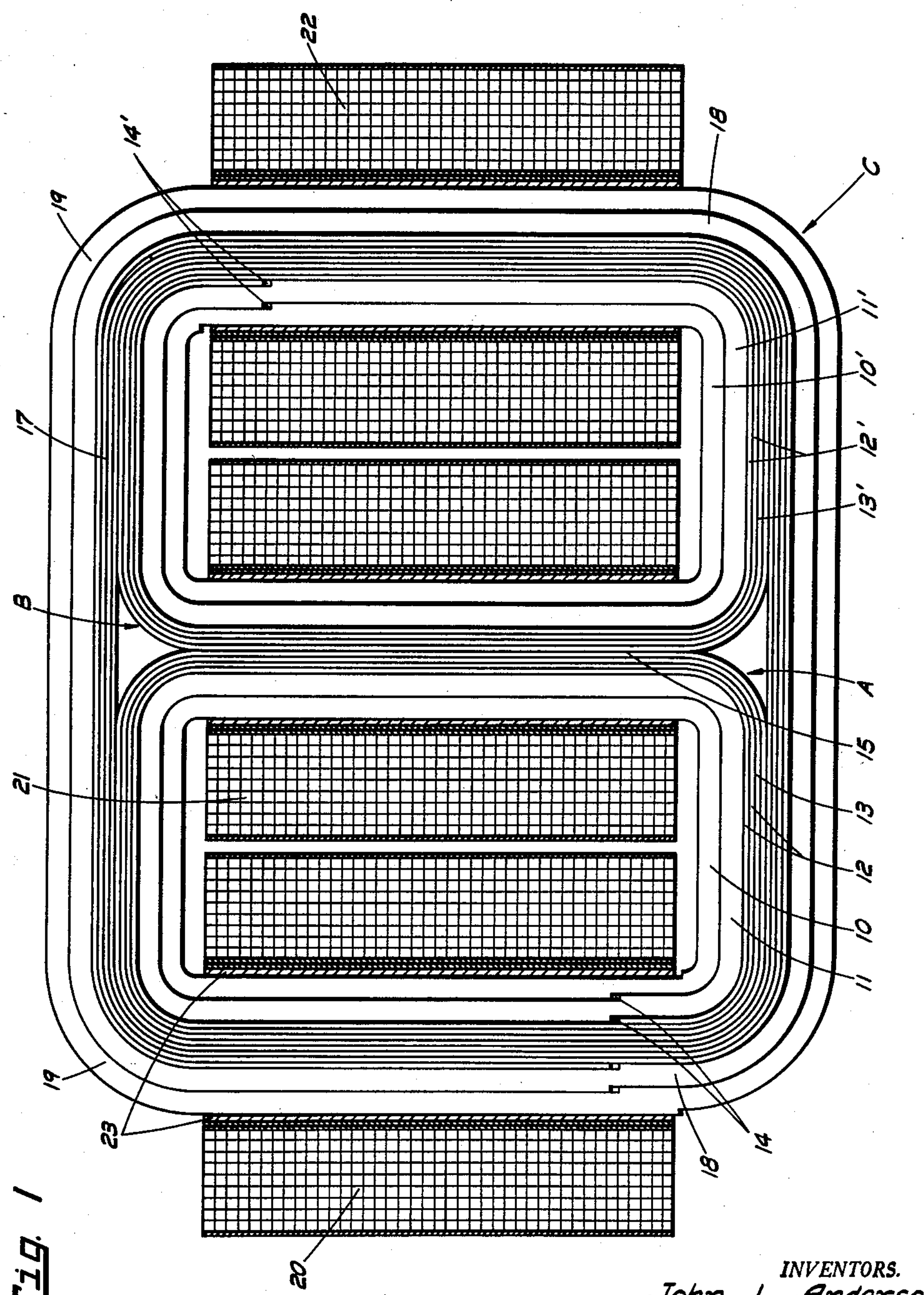

Fig. 1

INVENTORS.
John L. Anderson
James G. Everhart
BY Lee H Kaiser
Attorney

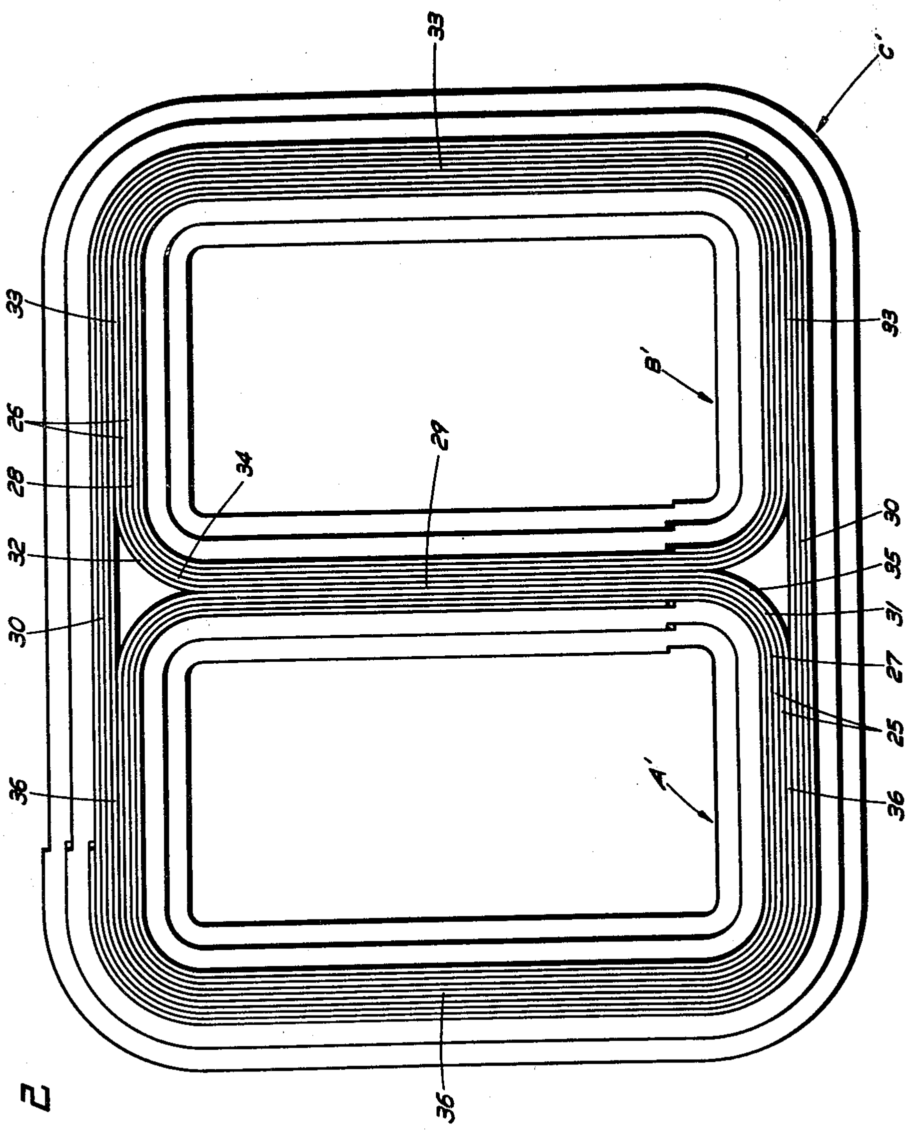

Fig. 2

INVENTORS.
John L. Anderson
James G. Everhart
BY: Lee H Kaiser
Attorney

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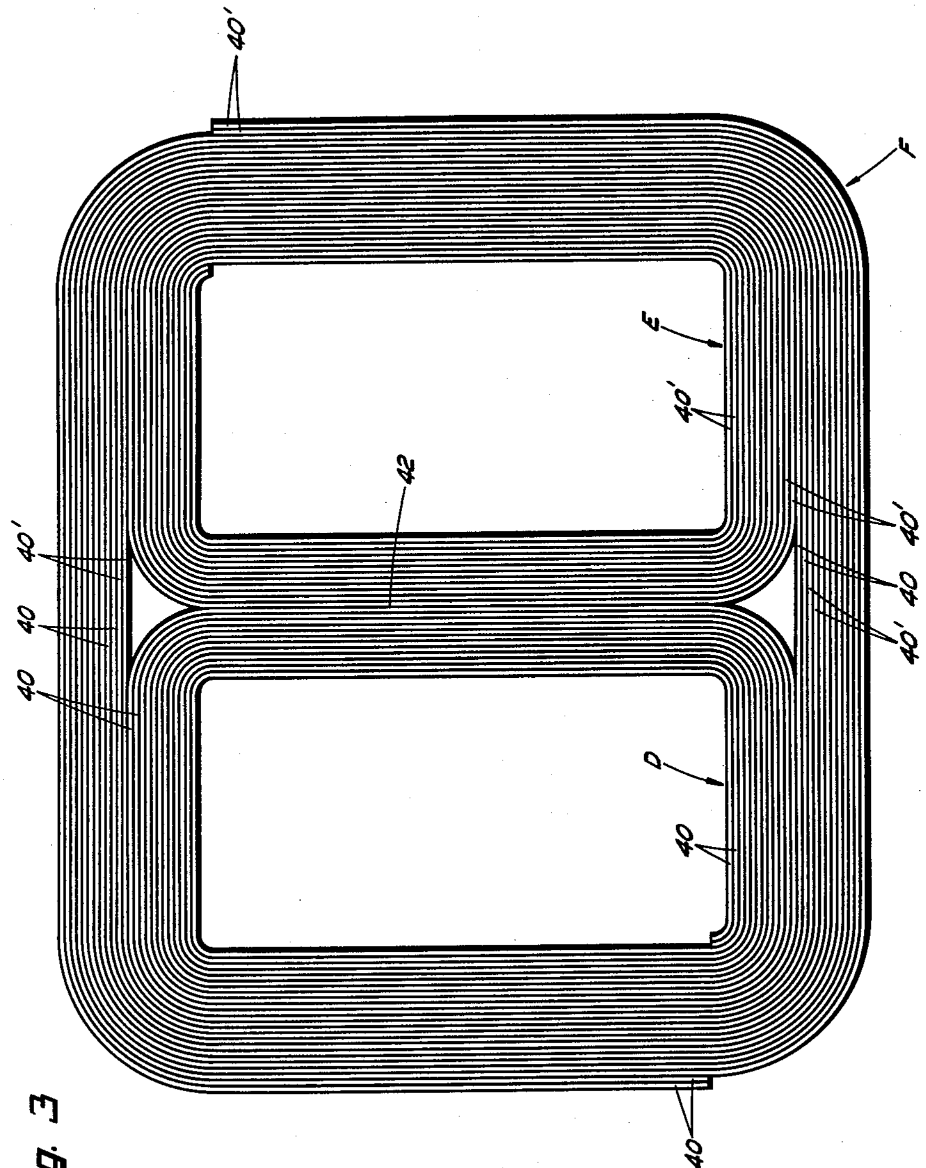

Fig. 3

INVENTORS.
John L. Anderson
James G. Everhart
BY: Lee H Kaiser
Attorney

3,101,525

METHOD OF MAKING POLYPHASE TRANSFORMERS

John L. Anderson and James G. Everhart, Zanesville, Ohio, assignors to McGraw-Edison Company, a corporation of Delaware

Original application Apr. 12, 1954, Ser. No. 422,374, now Patent No. 2,946,028, dated July 19, 1960. Divided and this application Mar. 28, 1960, Ser. No. 21,848
5 Claims. (Cl. 29—155.57)

This invention relates to polyphase transformers and is particularly directed to an improved method of magnetic core construction for polyphase transformers.

This application is a division of our application Serial No. 422,374, filed April 12, 1954, now U.S. Patent 2,946,028.

This invention is an improvement on the method of construction of the transformer which forms the subject matter of the Link Patent No. 2,431,128, granted November 18, 1947, and assigned to the assignee of the subject invention. The core disclosed in the Link patent comprises two inner, wound strip, closed core loops mounted back to back and surrounded by an outer, closed core loop wound from magnetic ribbon. The adjacent sides of the two inner core loops constitute the center winding leg while the outer sides of the inner core loops and the abutting sides of the outer core loop constitute the two outer winding legs of the three phase core. In such a core, it is necessary for some of the flux to pass from loop to loop, but this is extremely difficult because the reluctance to flux travel in a direction perpendicular to the laminations is quite high. Thus, most of the flux from the center winding leg cannot return through the entire cross section of the outer winding legs and is principally concentrated in the portions of the outer legs formed by the inner core loops.

An object of the invention is to construct a unitary magnetic core having at least two distinct closed magnetic circuits of lengthwise bent laminations interconnected by low reluctance iron paths to permit flux transfer between said circuits.

A further object of the invention is to construct a unitary, multi-legged magnetic core in which all portions of the core are integral and wound from magnetic strip which is continuous throughout the core.

Another object of the invention is to provide an improved method of constructing a three phase transformer having an 8-shaped core of the wound strip type wherein it is unnecessary to rely completely on flux leakage through high reluctance air paths to interlink the inner and outer core loops and wherein these portions of the core are directly interlinked magnetically by low reluctance iron paths.

Still another object of the invention is to provide an improved method of constructing a three phase transformer having a three legged, wound strip core wherein a direct iron path is provided for transfer of flux from the center winding leg to the outer core loop.

In accordance with the invention, the inner and outer loop portions of the core are magnetically interlinked by low reluctance iron paths preferably having grain orientation in the direction of flux travel. The outer loop portion is wound as a continuation of the magnetic ribbons of the inner loop portions to provide a direct iron path for transfer of flux between inner and outer loop portions. By means of this construction, the flux from any winding leg has return paths including the entire cross section of the iron of the other winding legs.

The invention will be better understood from the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appending claims.

In the drawing:

FIG. 1 is an elevation view of one embodiment of the invention;

FIG. 2 is an elevation view of an alternative embodiment which permits more efficient flux transfer than the embodiment of FIG. 1; and

FIG. 3 is an elevation view of an alternative embodiment wherein a plurality of magnetic ribbons interlink each inner loop portion with the outer loop portion.

Referring to the drawing and more particularly to FIG. 1, it will be seen that the transformer core structure comprises two inner loop portions indicated generally by the reference characters A and B, and an outer continuation loop portion indicated generally by the reference character C surrounding the inner core portions A and B and wound from the magnetic ribbons of the inner loop portions. Each of the inner loop portions is formed by winding a closed core of magnetic ribbon. Although any suitable magnetic ribbon may be utilized, it is preferable to utilize silicon steel having a preferred orientation of the grain lengthwise of the direction of winding.

The inner loop portions A and B are both formed in an identical manner and only portion A will be described. The parts of inner portion B are given the same reference numerals as those of inner portion A with the addition of the prime (′) designation. Although each inner loop portion may be formed from a single continuous ribbon spirally wound flatwise to provide a rectangular cross section, in the embodiment illustrated in FIG. 1 various widths of strip are utilized to build up cruciform-in-cross-section inner loop portions A and B. A magnetic ribbon of suitable width is first spirally wound flatwise to provide a closed core section **10** of desired thickness. The principal novelty of the invention resides in the provision of direct iron paths between inner and outer loop portions, and inasmuch as the inner two sections of the inner loops and the outer two sections of the outer loop of the embodiment of FIGS. 1 and 2 are similar to prior art constructions, the convolutions of these sections have been omitted from the drawing to direct attention to the principal novelty. The winding is preferably on a rectangular mandrel, although it is within the scope of the invention to wind on a circular mandrel and thereafter shape the core section to rectangular configuration. A magnetic ribbon of greater width is then wound over the ribbon of the inner section **10** to form a closed core section **11**. Thereafter a magnetic ribbon **12** of still greater width is wound around the convolutions of the core section **11** to form a closed core section **13**. The ribbon **12** is not severed after the desired number of turns have been wound.

It is well known in the art that when the winding of a core section is completed, the outer end of the magnetic ribbon may be brazed, tack welded, or otherwise secured as indicated by the reference numeral **14** and further that the ends of successive magnetic ribbons may be joined by welding or brazing, if desired. However, it has been found satisfactory to laterally slit each ribbon near its end across a portion of its width, and to "dovetail" the slit ends in a manner analogous to a blind-halved lap joint.

Two closed, substantially rectangular, core inner portions, or loops, A and B having a free length of uncut magnetic ribbons **12** and **12′** respectively continuous therewith are mounted on a rotatable base (not shown) with their longer sides abutting. The manner of mounting the inner loops A and B on a common arbor does not constitute part of the present invention and is not illustrated in the drawing. It is apparent that the rectangular mandrels (not shown) on which the loops A and B are originally wound can be supported directly on the base which is then rotated to wind the outer core loop, or, if desired, the inner portions A and B can be first removed from the rectangular mandrels before being mounted on the rotatable base.

The base (not shown) is then revolved to simultaneously rotate the two inner loop portions A and B as an integral entity with their longer sides abutting. Upon continued rotation of the base, a closed outer core section **17** is spirally wound to the desired thickness surrounding the inner two core sections A and B with the two ribbons **12** and **12'** in parallel in each spiral layer.

The number of laminations in a radial cross section through the final core may be in the hundreds, and the impossibility of illustrating all of the convolutions in the drawing is obvious. Consequently, the thickness of the magnetic strip is greatly exaggerated in the drawing and tends to give the impression that the joints between successive strips would cause bulges in the core portions radially outward therefrom. However, when it is considered that the thickness of the individual convolutions is usually measured in thousandths of an inch and that such joints may be staggered peripherally, it will be appreciated that the joints do not appreciably affect the shape of the final core.

The next step is to wind a single narrower magnetic ribbon, of approximately the same width as the ribbons of sections **11** and **11'**, into a closed core section **18** surrounding the core section **17**. Here also the convolutions of the section **18** are omitted from the drawing. The ends of the ribbons **12** and **12'** are preferably staggered peripherally, and the end of the single magnetic strip from which the section **18** is wound may be brazed, tack welded, or otherwise secured to one or both strips **12** and **12'**, or may be joined thereto by slitting the magnetic ribbons near their ends across a portion of their width and dovetailing the slit portions. Thereafter, a narrow magnetic ribbon having a width approximately equal to that of the ribbons forming the core sections **10** and **10'** is wound into a closed core section **19** surrounding the section **18** and its end is tack welded, brazed, or secured by a peripheral clamping band encircling the outer loop C.

It is to be noted that the three phase transformer has a central leg formed by the abutting straight sides of the inner loops A and B and has two outer legs formed by the abutting outer straight sides of the inner loops A and B and the spaced straight sides of the outer loop C.

The entire core is then annealed so as to remove all stresses due to the working of the magnetic ribbon during winding. After annealing there is no further working, machining, or bending of any of the magnetic ribbons and consequently there is no stress imparted to any portion of the core which would otherwise adversely affect the characteristics of the transformer.

The conducting winding assemblies, or electrical coils, **20**, **21** and **22**, including primary and secondary windings, are wound on the finished annealed core in any suitable manner, preferably by the apparatus disclosed in the Patent 2,305,999 to Steinmayer et al. dated December 22, 1942. The outer straight portion of the inner core loop A and the abutting straight portion of the outer core loop C pass through the winding window of the electrical coil **20** to form one outer leg; the abutting back to back straight portions of the inner core loops A and B pass through the winding window of the electrical coil **21** to form the central leg **15**; and the outer straight portion of the inner core loop B and the abutting straight portion of the outer core loop C pass through the winding window of the electrical coil **22** to form the other outer leg.

After the conducting windings have been finished, suitable wedges **23** may be driven in place as shown to suitably hold the electrical coil assemblies firmly positioned with reference to their winding legs.

In order to simplify the drawing and to facilitate the understanding of the invention, the electrical coil assemblies **20**, **21** and **22** are omitted in FIGS. 2 and 3 of the drawing. The embodiment of FIG. 2 is similar to that of FIG. 1 except that a more efficient interlinkage of flux between core loops is obtained. Two inner core loops A' and B', substantially identical to the inner loops A and B of the embodiment of FIG. 1, are mounted on the rotatable base so that their direction of winding is the same (for example, counterclockwise) and with the unsevered magnetic ribbons **25** and **26** from the outer sections **27** and **28** of the inner loops A' and B' respectively extending from opposite ends of the central leg **29**. The base is then rotated in the opposite direction from that in which the inner core loops A' and B' were wound, i.e., clockwise, to spirally wind the two ribbons **25** and **26** in parallel around the inner loops A' and B' in order to construct the inner section **30** of the outer loop C'.

The effect is that the magnetic ribbon from the outer section of each inner loop is wound in the reverse direction to complete a closed flux path around the other inner loop before the winding of the outer loop C' is initiated. The magnetic ribbon **25** of the outer section **27** of the inner loop A' is illustrated as wound counterclockwise with the outer laminar convolution **31** thereof separating from the upper end of the central winding leg **29** where indicated by the reference numeral **32**. The ribbon **25** is then continued in the opposite direction, i.e., clockwise, in a turn **33** around the inner loop B' before the two ribbons **25** and **26** are paralleled and spirally wound together clockwise to form the inner core section **30** of the outer loop C'.

The magnetic ribbon **26** of the outer section **28** of the inner loop B' is shown as wound counterclockwise, and the outer laminar convolution **34** separates from the lower end of the central winding leg **29** where indicated by the reference numeral **35**. The ribbon **26** is illustrated as continuing a clockwise direction in a turn **36** around the inner loop A' before the two ribbons **25** and **26** are paralleled and spirally wound clockwise together to form the inner core section **30** of the outer loop C'. Such construction more efficiently interlinks both inner core loops and further provides more efficient transfer of flux between the center winding leg **29** and the outer loop C' at both ends of the center winding leg **29**.

The embodiment of FIG. 3 is similar to that of FIG. 1 except that a plurality of magnetic ribbons interlink the inner and outer portions, or loops, of the core. Two inner core loops D and E are constructed in a manner similar to the embodiments of FIGS. 1 and 2 except that instead of varying the width of successive strips to provide cruciform cross section, in order to simplify the description and to aid in the understanding of the drawing the embodiment of FIG. 3 is illustrated with constant width magnetic strip throughout the core to obtain a radial cross section of rectangular configuration. Each spiral turn comprises a plurality of ribbons in parallel, two parallel ribbons **40** being illustrated in each convolution in inner loop D and two parallel ribbons **40'** in each convolution in inner loop E. Although the exaggerated thickness of the laminations permits the illustration of only two magnetic ribbons in parallel, it will be obvious that any desired number of ribbons may be so wound to interlink the inner and outer loops. As in the embodiment of FIG. 1, the ribbons **40** and **40'** are not severed after the desired number of turns have been spirally wound to form the inner core loops D and E.

The two inner loops D and E are then mounted on a rotatable base (not shown) with the free length of the uncut ribbons **40** and **40'** continuous therewith and with the straight portions of the longer legs abutting in the manner described for the embodiment of FIG. 1. Preferably the inner loops D and E are disposed on the base so that their direction of winding is the same and with the uncut magnetic ribbons **40** and **40'** extending from opposite ends of the central winding leg. After half a revolution of the rotatable base (not shown), the ribbons **40** and **40'** of the two inner portions D and E are in parallel, and upon continued rotation of the base, the ribbons 40 and 40' are spirally wound to tightly and closely embrace the abutting inner portions D and E. The four parallel ribbons 40 and 40' are continued to form a closed outer core loop F having approximately the same thickness as the inner loops D and E. The ends of the magnetic ribbons 40 and 40' are secured by brazing, welding, or by a peripheral clamping band encircling the outer core loop F.

The invention provides a unitary polyphase transformer construction which utilizes the wound core principle and in which the inner and outer portions, or loops, of the core are directly interlinked by ferromagnetic paths. It is to be noted that there are no air gaps in the magnetic path and that low reluctance iron paths interlinking the inner and outer portions of the core have the grain of the magnetic ribbon in the direction of flux travel. It will further be noted that a direct iron path is provided for the flux of the middle winding phase, i.e., the center winding leg, to transfer into and return from that portion of the outer winding legs formed by the outer loop of the core. The flux from any winding phase can thus return through the entire cross section of the other winding legs without transferring through high reluctance air paths perpendicular to the laminations as in three legged, three phase cores heretofore constructed.

Although the method of construction has been described as including the mounting of two inner core loops as an integral entity on a rotatable base to wind the outer loop, it will be appreciated that the method described is merely illustrative and that the disclosed transformer core is capable of construction by other means, e.g., the outer core loop may be wound manually, if desired. The description has been limited to a three legged, three phase transformer, but it will be appreciated that the invention comprehends any transformer of the type having lengthwise bent, concentrically stacked laminations wherein it is desirable to interlink portions of the core with low reluctance iron paths.

While only three embodiments of the invention have been illustrated and described, it will be obvious to those skilled in the art that changes and modifications can be made without departing from the invention, and therefore it is intended in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. The method of constructing a wound strip, three legged, magnetic core comprising the steps of spirally winding magnetic ribbon flatwise to form a first convoluted loop and spirally winding magnetic ribbon flatwise to form a second convoluted loop and retaining a free length of magnetic ribbon extending from at least one of said loops and continuous with the outer convolution of magnetic ribbon of said one of said loops, mounting said loops on a common rotatable member with adjacent sides abutting, and rotating said member to spirally wind said free length of magnetic ribbon into a convoluted loop surrounding said abutting loops in embracing relation thereto.

2. The method of constructing a magnetic core having three parallel, spaced apart legs having a common central plane, comprising the steps of spirally winding a plurality of magnetic ribbons flatwise in parallel to form a first inner convoluted core loop and retaining uncut magnetic ribbons extending from said first loop and continuous with the magnetic ribbons of the outer convolution of said first loop, spirally winding a plurality of magnetic ribbons flatwise in parallel to form a second inner convoluted core loop and retaining uncut magnetic ribbons extending from said second loop and continuous with the magnetic ribbons of the outer convolution of said second loop, mounting said inner loops with adjacent sides thereof abutting on a common rotatable member, and rotating said member to spirally and flatwise wind said uncut magnetic ribbons in parallel into an outer loop surrounding said inner loops in embracing relation thereto.

3. The method of constructing a three legged magnetic core comprising the steps of forming a first rectangular multilayer loop of flatwise bent laminations of magnetic strip material and retaining an uncut length of magnetic strip material extending from said loop and continuous with the outer layer of magnetic strip material thereof, forming a second rectangular multilayer loop of flatwise bent laminations of magnetic strip material and retaining an uncut length of magnetic strip material extending from said second loop and continuous with the outer layer of magnetic strip material thereof, disposing said first and second loops in a common plane with adjacent sides abutting, and flatwise bending said uncut lengths of magnetic strip material from said first and second loops in parallel in embracing relation to said abutting first and second loops and forming an outer multilayer loop of flatwise bent laminations of magnetic strip material surrounding said first and second loops with said uncut lengths constituting at least the inner layer thereof.

4. The method of constructing a wound, three legged magnetic core, comprising the steps of flatwise winding a portion of a first magnetic ribbon to form a closed, convoluted, first magnetic core portion, flatwise winding a portion of a second magnetic ribbon to form a closed, convoluted, second magnetic core portion, disposing said first and second core portions in a common plane with adjacent sides abutting, and continuing the winding of said first and second magnetic ribbons to form a closed, convoluted, third magnetic core portion embracing the abutting first and second core portions.

5. The method of constructing a magnetic core having n legs where n is an integer having a magnitude of three or more, comprising, in combination, the steps of forming $n-1$ rectangular multilayer loops of lengthwise bent laminations of magnetic strip material and retaining an uncut legnth of magnetic strip material extending from at least one of said loops and continuous with the outer layer of magnetic strip material of said one loop, positioning said loops in a common plane with peripheral surfaces of adjacent loops in abutting relation, and lengthwise bending said uncut length of magnetic strip material into embracing relation to said abutting loops and forming an outer multilayer loop of flatwise bent laminations of magnetic strip material surrounding said abutting loops with said uncut length constituting at least the inner layer thereof.

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