Aug. 11, 1959

J. R. SMITH

MAGNETIC CORE

2,899,656

Filed Jan. 11, 1954

2 Sheets-Sheet 1

Fig. 3.

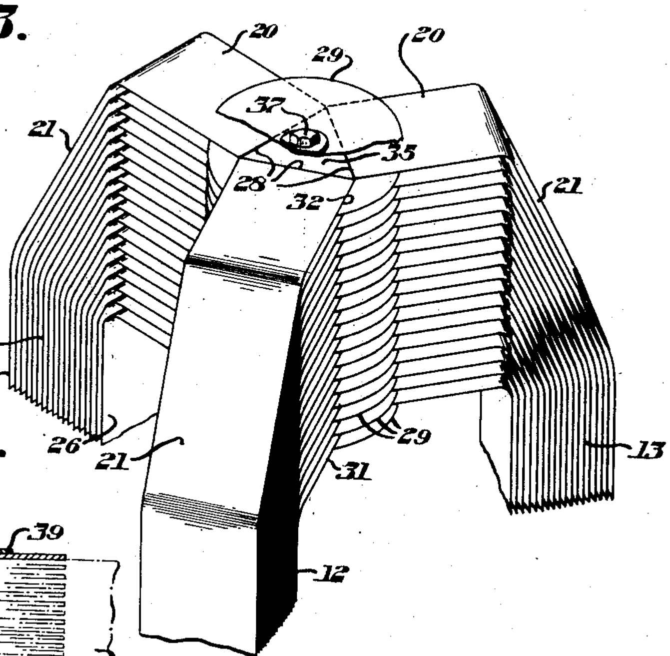


Fig. 4.

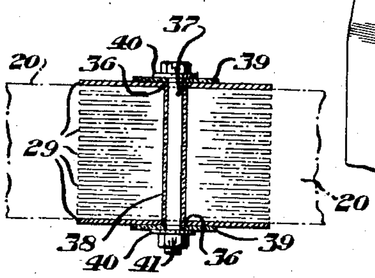
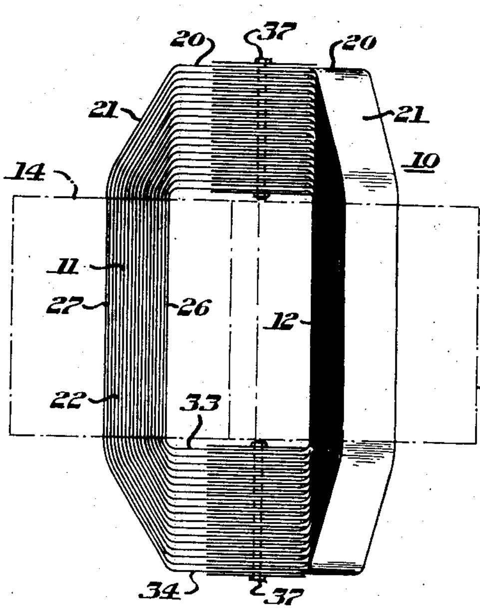


Fig. 2.

Fig. 1.



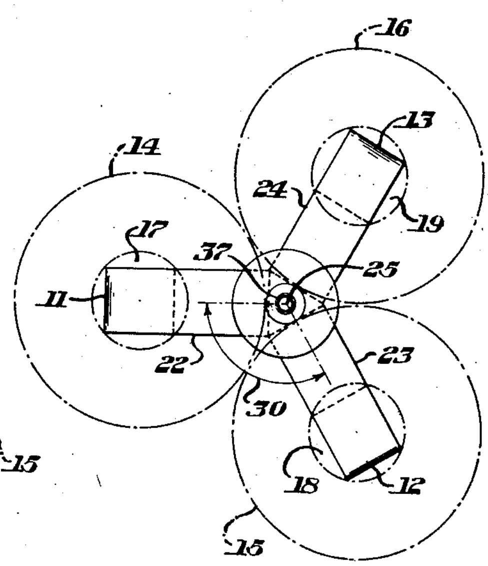


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Fig. 5.

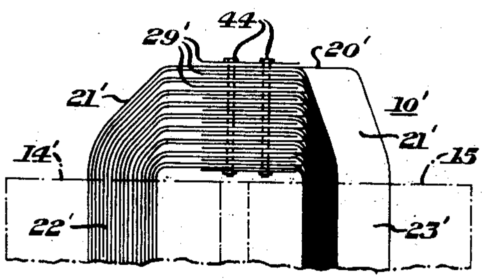


Fig. 6.

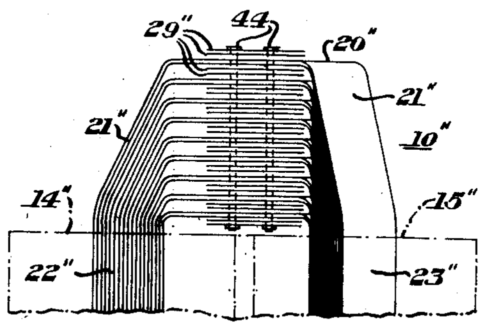


Fig. 7.

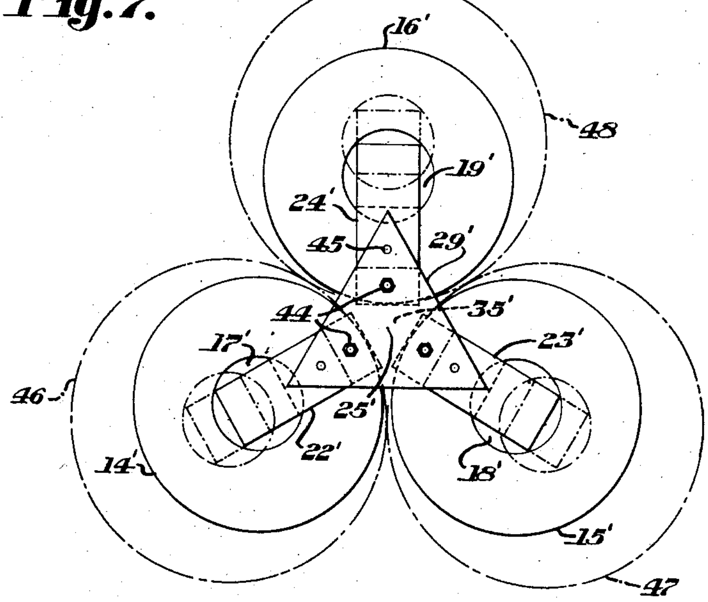
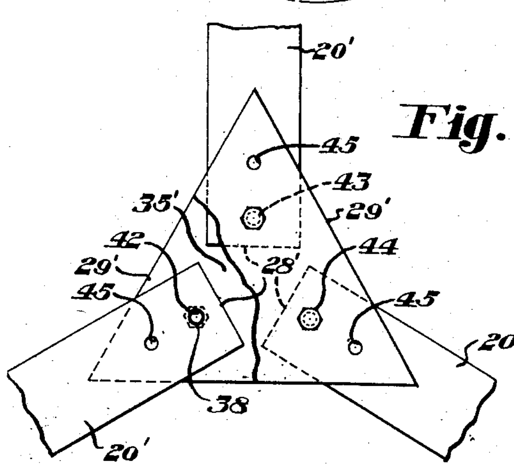


Fig. 8.



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MAGNETIC CORE

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8 Claims. (Cl. 336—211)

This invention relates to a new multiphase magnetic core for use in electrical transformers or the like. More particularly, this invention pertains to such a magnetic core in which a plurality of radially nested half turns of core steel are positioned in angularly spaced relation with a common plate of magnetic steel lapping the ends of the half turns.

Multiphase magnetic cores for electrical transformers and related devices have heretofore been constructed in a variety of ways. In some cases in order to develop a satisfactory space factor between the coil and core steel, which preferably is a cold-rolled oriented grain electrical steel, an outer core surrounding two individual cores in side-by-side relation has been utilized. In those cases, the mean turn length of the surrounding core is relatively great and some departure from ideal magnetic flux flow conditions has resulted. In other cases, individual magnetic cores have been placed in side-by-side relation with loss of the full effectiveness of the outermost winding legs of the multiphase core structure. In still other situations, individual magnetic cores have been arranged, when viewed in plan, in the form of an equilateral triangle but those situations have resulted in difficulty in linking the core with the electrical coil windings, or have occasioned an undue number of joints tending to unduly increase the reluctance in the magnetic flux paths. In still other prior multiphase cores, special shapes have had to be resorted to with curved reaches in some cases, or other special shaping, or interfitting. Moreover, in many of such prior multiphase magnetic cores, the magnetic paths of respective turns have not been relatively independent electrical paths but ones which required flux crossover. Multiphase cores have also been made so as to radiate, when viewed in plan, from a more or less central axis. In these latter cases, numerous and relatively difficult interfitting manipulations have been required with resulting relatively high joint reluctance in some of them. As a consequence, the magnetic core industry continues to seek an appropriate solution for its difficulties.

In my new construction, such difficulties of prior practices are markedly reduced, or overcome. Thus, in my invention a new multiphase magnetic core is provided which can make full use of the electrical properties of cold-rolled oriented grain electrical steel. In addition, my new magnetic core enables such core steel to be utilized in radially nested form with the plane of the core steel strip in "wound" or tangential relation to the turns of the electrical coils, preferably preformed, with which my new core is to be used. Moreover, linking of the respective winding legs of my new multiphase magnetic core with such coil windings is a simple and efficient operation and one which in the final transformer or device using my new magnetic core, yields high performance characteristics. Still further, in my invention, a minimum of core steel for maintenance of given standards is made possible. At the same time, the relatively smaller size of a transformer or the like utilizing my new magnetic core enables a reduction in cost to be accomplished in many of the other items incorporated in such transformer or the like, such as, for example, the tank and the amount of dielectric liquid utilized therein. A further object and advantage of the present invention is the presence in each turn of the new core of joints which are lap joints, enabling me to avoid the detriment of flux crossover and flux maldistribution which plagues some prior practices.

Other objects and advantages of this invention will be apparent from the following description and from the accompanying drawings, which are illustrative only, in which:

Figure 1 is a view in side elevation of one embodiment of my new multiphase magnetic core intended to be utilized in a three-phase distribution or power transformer;

Figure 2 is a plan view of the new construction shown in Figure 1;

Figure 3 is a view in perspective and somewhat enlarged of the upper portion of the new structure shown in Figures 1 and 2;

Figure 4 is an illustration of one mode of holding a new core together in a joint area thereof;

Figure 5 is a modified view of a new multiphase magnetic core of this invention;

Figure 6 is a further modification of a new multiphase magnetic core of this invention;

Figure 7 is a plan view of a construction such as that shown in Figure 5 (or in Figure 6) when incorporating my new provision for changing the coils of a transformer embodying my new multiphase magnetic core; and

Figure 8 is a detail view of the holding construction shown in Figure 7.

Referring to the drawings, my new multiphase core principle may be embodied, for example, in a three-phase core **10**. Core **10** in turn may comprise three winding legs respectively numbered **11**, **12** and **13** which are preferably straight and with which preformed electrical coils **14**, **15** and **16** may be magnetically linked. Thus, as shown, leg **11** passes axially through window **17** of coil **14**, leg **12** through window **18** of coil **15** and leg **13** through window **19** of coil **16**. Although winding legs **11** to **13**, inclusive, are rectangular in the embodiment illustrated, it will be realized that the cross section of such legs may be cruciform or otherwise made to provide whatever space factor is desired relative to the windows of the respective coils.

Each side of the new core **10**, in the embodiment shown, is identical and comprises a straight portion which is one of the aforesaid winding legs, a straight portion **20** which is a yoke section and an oblique or curved portion **21** connecting the yoke section with the winding leg portion or section in each lamination. Thus, the three sides respectively numbered **22**, **23** and **24** are relatively channel-shaped in profile, as shown in Figure 1, with the flanges of the channel being represented by the upper and lower yoke sections **20** and the web of the channel being represented by the winding leg sections **11**, **12** or **13** as the case may be. Although reference is made in this description to upper and lower portions or to top and bottom of the new core **10**, it will be realized that such new core may be utilized with its axis **25** in any position that may be desired.

The sides **22** to **24**, inclusive, therefore comprise half-turns in radially nested or "wound" arrangement with the flat surfaces of adjoining laminations in each side as close together as the particular construction method employed permits. It is evident that innermost turn **26** of side **22** is considerably shorter than outermost turn **27** of that side. The nested laminations of core steel strip utilized in making up each side will increase in length progressively from the inside to the outside of the side in question so that the end edges **28** are substantially in axial alignment with each other in each such side of my new magnetic core in the embodiment shown.

The progressive lengths of individual laminations forming of the individual half-turns in each core side, may be formed in more than one way. Thus, core steel strip of appropriate width or widths as the case may be may be wound on a quadrilateral mandrel and three such continuous spirals of appropriate radial thickness may be made. Thereupon, those core steel strip spirals may be sawn or milled in half through the center of the sides of the spirals which are to serve as yoke sections and the six half spirals so produced may be utilized in constructing two of the new multiphase cores such as illustrated in the drawings. As will be understood, before such half spirals become core sides, the progressively longer laminations in each of the half spirals will have to be stacked and shaped, for example, in the shape shown in the drawings and then annealed to preset such shape and restore the electrical properties of the core steel which may have been somewhat impaired by the spiraling and halving operation. In such winding of the core spirals, any convenient spacing arrangement that may be needed, may be provided to insure proper stacking and nesting in the final core made therefrom. Alternatively, such progressive lengths of core steel strip, before stacking, shaping and annealing, may be made on a progressive length change indexing and cutting machine of the kind presently available on the market. Such alternative method does not require any spacing provision during such cutting. In either fabrication method of making elements for my new core, spacers may be inserted in the stacking and shaping operations before annealing between adjoining yoke sections **20** in each side to accommodate the thickness of my new lap plates **29**.

Each side of my new core may readily be linked with a preformed coil since as annealed the core steel is readily flexible even though preset and the yoke sections **20** of adjoining laminations in groups of two or more may be inserted endwise into the end of a window of the coil without exceeding the elastic limit of the annealed core steel. Preferably, such groups should be inserted beginning with the innermost half-turns including turn **26** and successively outer groups should follow until each side is linked with its respective electrical coil or coils as the case may be in position surrounding the winding leg of that side. Thereupon, top and bottom end edges **28** of two of the sides **22** to **24**, inclusive, may be brought into the relation shown in Figures 2 and 3 with the "planes" of such sides being angularly spaced 120 degrees as shown by arrow **30**. At that point, lap plates **29** are inserted which in the form shown are flat discs of magnetic metal such as steel. Such plates **29** may be stamped out at relatively low cost and preferably are annealed before being utilized in a new magnetic core. Such plates **29** are interleaved between the yoke sections in each tier beginning with tier **31** and ending with tier **32** in the upper joint portion of the new core while the similar provision is made in the bottom joint portion between tier **33** and tier **34** of the yoke sections **20** in that area.

Assuming that sides **22** and **23** are first brought together and plates **29** engaged therewith as shown in the drawings, it is a relatively simple matter to then advance side **24** with its linked coil **16** toward the plates **29** for engagement therewith as also shown in the figures, the end edges **28** of side **24** completing an equilateral space triangle **35** in the plane of the yoke sections **20** in the same tier of the respective tiers on each end of the respective core. It will be noted that the overlap area between each yoke section **20** and the plates **29** engaging such yoke sections is sufficient to avoid any restriction of the flux flow and to inhibit flux crossover between tiers. Moreover, because of plates **29**, at each instant, the magnetic path between the respective yoke sections **20** will remain in substantial electrical balance for optimum operation in the course of service of the new core **10**.

As shown in Figure 4, one mode of holding the joint zones and the plates **29** with the yoke sections **20** in aligned engagement in each such zone, may be simply and readily accomplished. Thus, the centers of the plates **29** may be provided with drilled openings **36** through which a bolt **37** passes inside of an insulating sleeve **38**. The ends of the sleeve are continued in the form of adjoining insulating washers **39** which are axially inwardly of metal washers **40** against which the head of bolt **37** and a nut **41** respectively bear when the nut is tightened. Such tightening correspondingly compresses the plates **29** and makes firm engagement between such plates **29** and the respective yoke sections **20** with which such plates are in contact. The insulating sleeve **38** is of a sufficiently flexible quality that its foreshortening in such tightening is possible without the diminution of its insulating effect.

In the modification illustrated in Figure 5, corresponding parts having the same general construction and function are provided with the reference numerals applied to the construction shown in Figures 1 to 3 with the addition of a prime factor thereto. In such Figure 5 modification, the half turn laminations **22′** and **23′** substantially define an equilateral triangular column **35′** between the respective ends of the half turns of core sides **22′**, **23′** and **24′**. The column **35′** is spanned in the respective tiers in which lap plates are used, by such lap plates. As in the embodiment shown in Figure 2, the ends of the turns in each side of the new core shown in Figure 5 and Figure 7 substantially define a plane parallel to the axis **25′**. Moreover, in the modification of Figure 5, lap plates **29′** are triangular as more particularly shown in Figure 7 thereby conserving magnetic material used to make such lap plates. In the modification of Figures 5 and 7, the ends of pairs of laminations in each side are in contact rather than each of the ends in a particular lamination being separated by a lap plate from the ends of the succeeding lamination as shown in Figures 1 and 3. In the Figure 5 modification, such pairs of ends of the core steel in contact are separated from adjoining pairs of ends by lap plates **29′** in the manner shown in Figure 5. The lap plates **29′** may be made of oriented or of unoriented grain core steel.

The modification shown in Figure 6 provides a pair of superimposed lap plates **29″** between each contacting pair of ends in each lamination. The lap plates and other elements in the further modification of Figure 6 with the same general construction and function as the parts shown in Figure 5 are given the same reference numerals with, however, a double prime factor. As shown, the "build-up" in the case of the Figure 6 further modification is greater than that in any of the other embodiments of my new multiphase magnetic core. Hence, although the Figure 6 construction has a greater tendency to minimize magnetic reluctance at the lap plate joints at the end of the core steel half turns, such further modification normally requires more available headroom.

Although the embodiments illustrated are in a general Y appearance in plan, one of the half turn sides of my new magnetic core may be positioned in alignment with another of such sides and the third side may be placed at right angles thereto to establish my new magnetic core with a substantial T-shape appearance in plan.

As more particularly shown in Figure 7, the ends of the lamination half turns in the sides of the new core may be provided with punched or drilled openings **42** in registry with punched or drilled holes **43** in the lap plates **29′** or **29″** as the case may be. Thereby a bolt and nut **44** may be utilized and insulated from the respective lap plates and half turns to hold the sides of the core and the respective lap plates together at the upper ends and at the lower ends. Suitable supports for the new magnetic core in the form of a core frame and for the conductive windings or coils with which the new core is linked may be provided by any of the practices known to the electrical induction apparatus art. The lap plates **29'** or **29''**, as the case may be, may be provided with one or more further series of openings **45** radially displaced from the openings **43** so that if desired, the same new core may have the relative position of its sides changed, radially relative to the axis **25'**, for utilization with such sides of other electrical coils having different characteristic. In that way, a single transformer core structure of my new kind can serve to constitute an interchangeable underlying magnetic flow path structure for various coils with, as stated above, different ratings and/or voltage characteristics. Thus, as shown in Figure 7 by dot-and-dash lines, the core sides **22'**, **23'** and **24'** may be shifted radially outwardly to accommodate different coil windings **46**, **47** and **48** without alteration of the basic structure of the transformer or of the new core or of the parts entering into the new core.

Other modifications may be made in details of my invention without departing from the spirit thereof or the scope of the following claims.

I claim:

1. In combination, in a multiphase transformer core or the like, a plurality of radially nested generally C-shaped continuous half turns of bent strip forming a core side, each such core side having an intermediate portion utilizable as a winding leg for an induction coil, said half turns in each side being substantially geometrically similar in construction, a plurality of such core sides with the ends of the half turns in each thereof extending substantially straight across said half turns and generally equidistant from a common axis, said turn ends of said core sides being in generally unfitted relation in the respectively corresponding planes thereof, said sides being arranged generally radially so that said core has a spidered appearance when viewed axially, corresponding half turns in each side forming a core lamination with like positioned half turns in the remaining sides, pairs of said corresponding half turns in each core side being in contact relation at their respective turn ends, and at least one lap plate positioned in lap joint relation between each such pair of contacting turn ends in each core side, each such lap plate further being in like interleaved relation between corresponding turn ends of the other core sides in said respective planes.

2. In combination, in a three-phase magnetic core for a transformer or the like, three core sides surrounding a core axis and extending radially outwardly therefrom, each core side comprising generally C-shaped continuous half turns of bent strip in radially nested arrangement with the ends of the half turns adjacent said axis, the ends of corresponding half turns at each end of said core being geometrically similar and having at least the center of the edges thereof spaced from the centers of the edges of corresponding half turns at the particular core end in question, a lap plate in contact with each set of said ends of the corresponding half turns at each end of said core, said lap plates in contact with said respective ends substantially over the full width thereof, and means extending in the direction of said axis to hold said lap plates and ends at each end of said core in assembled relation to form a three-phase core.

3. In combination, in a magnetic core for a transformer or the like, comprising, a plurality of core sides, each core side having a plurality of radially nested one-piece half turns of flexible magnetic strip forming half turn laminations, said core sides having generally parallel yoke portions extending in intersecting directions at the top and bottom thereof respectively, said half turn laminations in each core side being of substantially geometrically similar construction and having at least the center of the respective edges thereof spaced from the center of the edges of corresponding half turns at the particular core end in question, the respective ends of said yoke portions of corresponding ones of said half turn laminations respectively being in generally proximate unfitted relation at the top and bottom of said core, and a plurality of lap plates of magnetic material in overlapping contact with corresponding ones of said yoke ends of respective laminations of said core at the top and bottom thereof.

4. In combination, in a multiphase transformer core or the like, a plurality of radially nested continuous half turns of bent strip of magnetic material forming a core side having yoke portions at the ends and an intermediate portion which may constitute a winding leg, a plurality of core sides in generally circumferentially spaced radial arrangement, said half turns in each side being geometrically similar and having ends formed by cutting generally abruptly across the width of said half turns, a plurality of such core sides being arranged with the respective ends of said yoke portions of said sides being adjacent, said ends substantially defining a spatial column the axis of which constitutes the axis of said core, said yoke portions in each core side extending generally in the same direction and to about the same distance toward said axis, and a plurality of lap plates of magnetic material extending across the space in said column to form interleaved lap joints with the adjoining ends of corresponding half turns respectively in each core side, said lap plates covering the ends of said half turns.

5. A magnetic core as set forth in claim 4, in which said lap plates are flat and of a conventional geometric shape, and in which said half turns have substantially square ends.

6. A magnetic core for a transformer or the like as set forth in claim 4, having a generally Y-shape and three such core sides circumferentially spaced approximately one hundred twenty degrees apart around said axis.

7. A magnetic core as set forth in claim 3, in which at least one of said core sides is positionally adjustable relative to the balance of the structure of said magnetic core.

8. A magnetic core as set forth in claim 3, in which at least one of said yoke ends and lap plates are provided with generally radially spaced holes, the other of said yoke ends and lap plates having holes in axial registry with a selected set of said first-named holes, and means passing through said holes in axial registry with said selected set to hold said core in assembled relation.

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