

Jan. 23, 1945.

L. W. CHUBB

2,367,927

THREE-PHASE TRANSFORMER CORE

Filed March 27, 1943

2 Sheets-Sheet 1

Fig. 1.

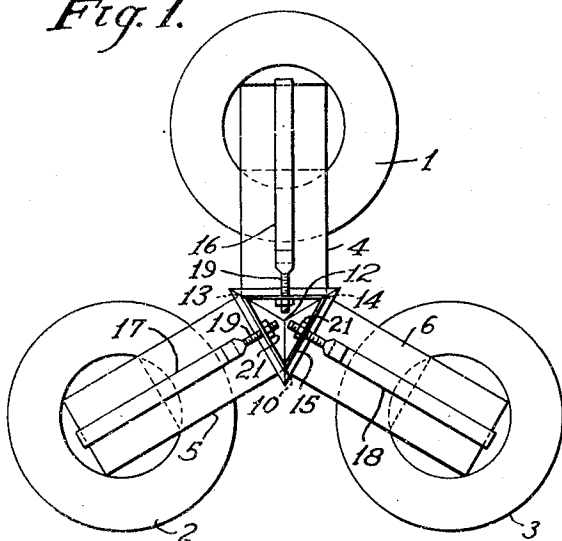


Fig. 3.

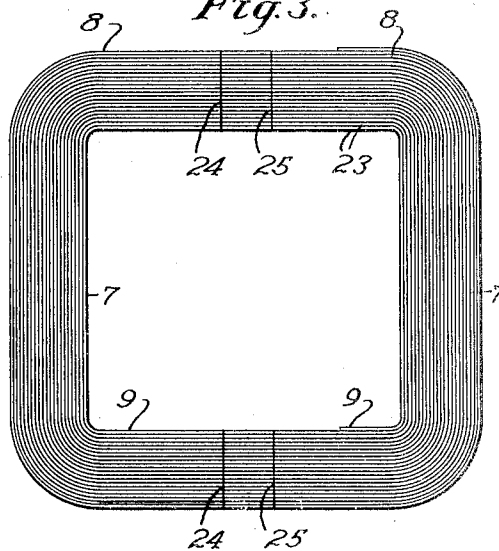


Fig. 4.

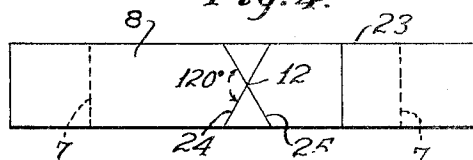


Fig. 2.

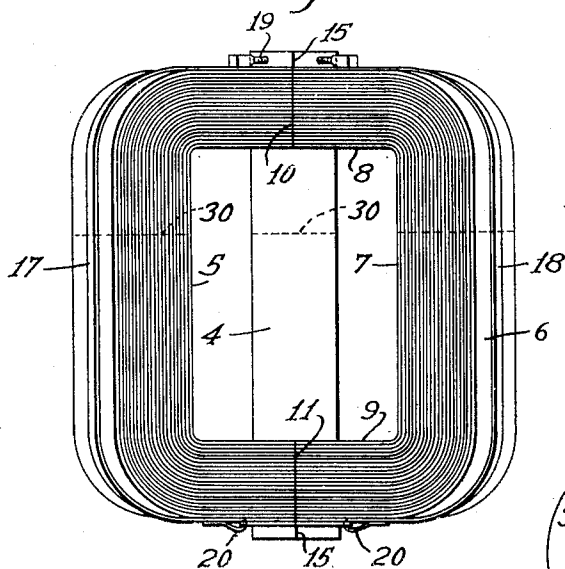


Fig. 5.

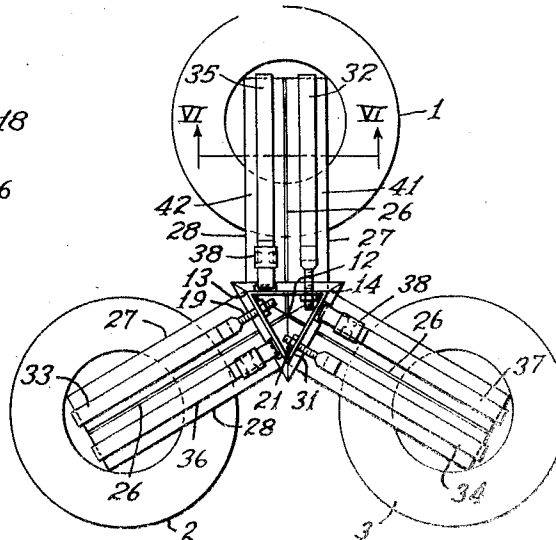
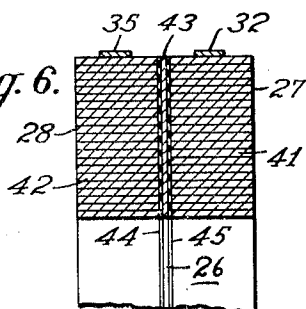


Fig. 6.



INVENTOR

Lewis W. Chubb.

BY

Franklin E. Hardy

ATTORNEY

Jan. 23, 1945.

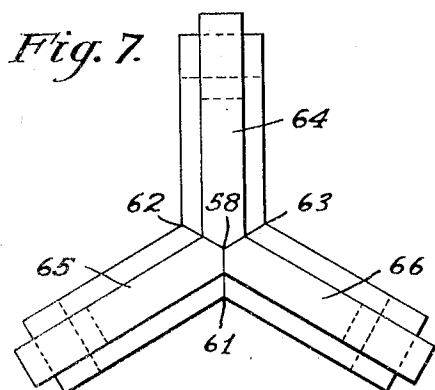
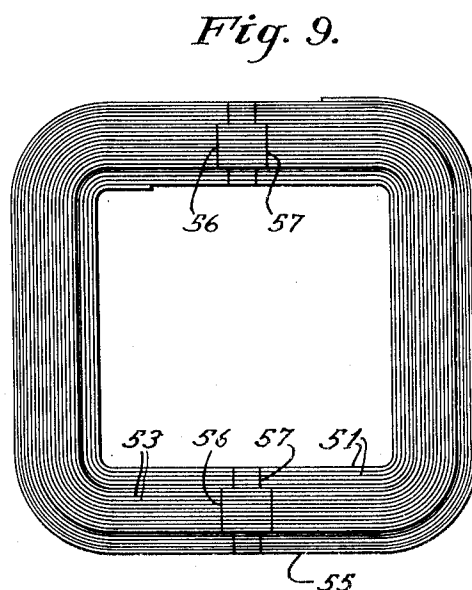
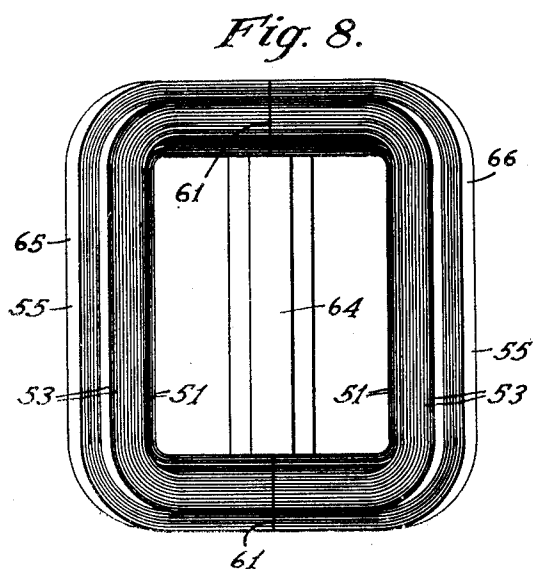
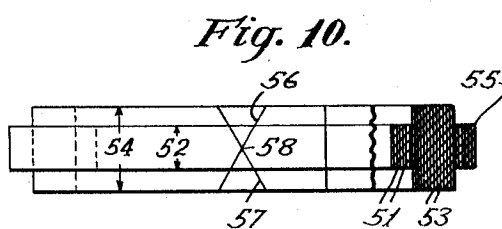
L. W. CHUBB

2,367,927

THREE-PHASE TRANSFORMER CORE

Filed March 27, 1943

2 Sheets-Sheet 2



WITNESSES:

Edward Michaels
Rev. C. Groome

INVENTOR

Lewis W. Chubb.

BY

Franklin E. Hardy
ATTORNEY

UNITED STATES PATENT OFFICE

2,367,927

THREE-PHASE TRANSFORMER CORE

Lewis W. Chubb, Churchill Borough, Pa., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application March 27, 1943, Serial No. 480,778

5 Claims. (Cl. 175—356)

My invention relates to electrical induction apparatus such as transformers, and particularly to the core or magnetic circuit structure thereof and to the method of making the same. More particularly, my invention relates to the core structures of three-phase induction apparatus used with alternating-current electric circuits in which separate sets of phase windings are provided for connection to the separate phases of a three-phase circuit.

Some commercial grades of steel with preferred grain orientation have better magnetic properties in the direction of rolling than in a direction at right angles to the direction of rolling. That is, when the lines of magnetic flux pass through the steel substantially in the direction of rolling, the core loss is less and the permeability of the steel is higher than when the lines of magnetic flux pass at an angle to the direction of rolling. To properly take advantage of the properties of this improved steel, it is necessary that the steel be so used that the direction of magnetization of the steel coincides substantially with the grain or direction of rolling of the steel so that the lines of magnetic flux shall not pass through the steel at an appreciable angle from the direction of rolling.

When continuously wound cores have been proposed or utilized for use with preformed coils, these cores have been cut and provided with butt joints at the cut surfaces in order to provide for ready assembly of the core parts about the preformed coils. Until recently, magnetic core structures having butt joints have been characterized by high iron losses and high excitation currents which prevent their successful operation at high magnetic densities, say 13 to 18 kilogausses, such as are otherwise possible when improved oriented magnetic steels are used.

In a copending application of J. K. Hodnette, Serial No. 401,699, filed July 10, 1941, for Induction apparatus, and assigned to the same assignee as this application, a core structure is disclosed that is formed of successive layers of magnetic sheet material wound flatwise layer upon layer and bonded together by filling the successive layers or turns of magnetic materials with bonding or filling material, thereby providing a solid or non-yielding laminated structure having a firm interlayer bond for all portions of the layers of sheet steel which is beneficial in producing a true and relatively unburred cut surface forming the faces of the butt joints.

In Patent No. 2,293,951 issued to J. B. Seastone and C. C. Horstman, August 25, 1942, for In-

duction apparatus and method of core construction therefor, and assigned to the same assignee as this application, a further development in the formation of low-loss butt joints is disclosed in which chemically inert bonding material is applied to the laminations. The core is cut, worked and etched to remove parts which could electrically connect adjacent laminations. In practicing the present invention, the teachings of the earlier filed Hodnette application and of the Seastone and Horstman patent in the formation of butt joints may be employed to increase the efficiency of the use of the steel.

It is an object of the present invention to provide a low loss core structure for use in polyphase electrical apparatus in which a plurality of winding core legs of magnetic material are employed and each is formed of sheets of magnetic material wound flatwise layer upon layer as above described.

It is a further object of the invention to provide a transformer core of the above indicated character in which the several winding leg members of the structure extend radially outwardly from a central axis and are equally spaced from one another.

The invention is disclosed in the embodiments thereof shown in the accompanying drawings and comprises the features of construction, combination of elements and arrangement of parts which will be exemplified in the constructions hereinafter set forth and the scope of the application of which will be indicated in the appended claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description, taken in connection with the accompanying drawings, in which:

Figure 1 is a plan view of a core and coil assembly arranged in accordance with one embodiment of the invention;

Fig. 2 is a side elevational view of the core shown in Fig. 1, with the coils removed;

Fig. 3 is a side elevational view of a loop of magnetic material which has been wound to form portions of the core structure and before this loop has been cut to form the separate core legs shown in Figs. 1 and 2;

Fig. 4 is a plan view of the loop shown in Fig. 3;

Fig. 5 is a plan view of a core and coil assembly using another modified form of core parts;

Fig. 6 is a sectional view along the line VI—VI on Fig. 5;

Fig. 7 is a plan view of another modified form of core structure;

Fig. 8 is an elevational view of the structure shown in Fig. 7;

Fig. 9 is an elevational view of the form of loop of magnetic material employed in building the parts of the magnetic structure shown in Figs. 7 and 8; and

Fig. 10 is a plan view of the core loop shown in Fig. 9 with a portion thereof shown in section.

Referring to Figures 1 and 2, a core and coil assembly is provided showing three sets of phase windings 1, 2 and 3, each set comprising primary and secondary windings for a particular phase in a well known manner. The core consists of three arch-shaped or U-shaped core pieces or members 4, 5 and 6 extending radially outwardly from a common axis and equally spaced circumferentially about the common axis. Each of the three core members comprises a substantially straight winding leg portion 7 and an upper and lower end portion 8 and 9 extending substantially at right angles to the straight portion 7 of the U-shaped member. The adjoining edges of the separate portion unite along a smooth butt joint indicated in Fig. 2 at 10 and 11, the joint extending from the edge 10 to the central axis 12 as shown in Fig. 1, where the several butt joint surfaces between the three core members unite, one of the three butt joint surfaces extending from the axis 12 to the outer edge 10 and the other two from the axis 12 to the outer edges 13 and 14, respectively, as indicated in Fig. 1.

A triangular-shaped frame member 15 is provided at each end of the core to which steel bands 16, 17 and 18 are attached so as to apply pressure to retain the core members 4, 5 and 6 in assembled position. The several bands may be attached to the frame 15 by loop portions 20 shown at the bottom of the core structure in Fig. 2, and at the upper end by means of a screw threaded portion 19 to which a nut 21 is applied for drawing the band to the proper tension.

Each arch-shaped core member comprising one leg of the core structure together with the yoke portions at opposite ends thereof interfitting with like yoke portions of the other members of the core, is built from magnetizable laminations of sheet steel 23 electrically insulated from each other and solidly held together with intervening bonding layers of an adherent insulating bond or filling material between the laminations. This bonding material is preferably a chemically inert material such, for example, as one of the well known resinous products which is applied to the laminations. Fig. 3 shows a strip of magnetic material wound continuously to provide a plurality of the laminations 23.

After the loop shown in Figs. 3 and 4 is wound to a predetermined shape and the layers of laminations are bonded together to form a solid structure, the core loop is then cut along plane surfaces indicated by the lines 24 and 25, best shown in Fig. 4, at the top and bottom of the core loop, these lines being along a plane at 60° to the front and rear faces of the loop to form plane surfaces intersecting at 120° to each other, so that three such members will accurately interfit to perform the complete core structure. The intersection between the surfaces 24 and 25 will be along the axis line of the core assembly.

Three such U-shaped members, 4, 5 and 6 will be required to form the core shown in Figs. 1

and 2. A single loop such as shown in Figs. 3 and 4, will provide two of the three members. In order to provide accurately smooth faces along the surfaces indicated by lines 24 and 25 shown in Figs. 3 and 4, cooperating with corresponding faces on the adjacent core members to form the three butt joints extending outwardly from the axis line 12 to the edges 10, 13 and 14, as shown in Fig. 1, to give the desired closely fitting butt joint, these faces are either machined or ground or otherwise mechanically worked to provide an accurately smooth surface in a true plane at the required angle to effect accurate interfitting of the three core members.

It has been found that during the machining or grinding operation to provide the smooth faces of the butt joints, burrs are formed. These burrs extend from one lamination toward the adjacent lamination and if not removed, may electrically connect or short circuit the adjacent laminations, thus resulting in high eddy currents and consequent high losses in the core structure. These burrs may be removed by applying an etching solution to the faces in any suitable manner. It has been found in practice that a 30% nitric acid solution is highly satisfactory. Other acid solutions, such as hydrochloric and sulphuric, have also been employed with success.

The phase coils for each of the three phases may be directly wound on the three U-shaped core pieces, or these U-shaped pieces may be cut in the leg portion 7, such as along the dotted lines 30 shown in Fig. 2, forming additional butt joints so that each one of the three core pieces comprises two sections that may be readily assembled within the coil assembly of preformed coils.

There are certain advantages in utilizing preformed current coils for the windings of an induction apparatus, among which are the application of high frequency testing and the inspection of the individual unassembled coils. These coils are wound on separate temporary formers or mandrels and are then assembled together with the magnetic core structure of the transformer or other induction apparatus with the required insulation and spacers.

Another satisfactory method of assembly would be to use the three U-shaped core pieces without the butt joints at 30 and wind the low voltage winding directly on the core leg portion, and to then build up the high voltage winding from a series of preformed disc or pancake type coils slipped over the end of the U-shaped core members. After this is done with each of the three phase portions of the core they are then assembled in place.

Referring to Fig. 5, a core and coil assembly is illustrated similar to that in Figs. 1 and 2 except that each core member associated with each one of the three-phase winding assemblies is formed of two pieces, so that two arched or U-shaped portions 41 and 42 lay side by side in each core member, one of these two portions being between the center or dividing line 26 as viewed in Fig. 5 and the outer edge 27, and the other between the dividing line 26 and the outer edge 28. In building this core structure, six pieces instead of three are required, each having a butt joint surface along a single plane at each end of the piece. The six pieces all join at the axis 12 and extend outwardly from the axis. Two such pieces extend along opposite sides of the three planes 26 which separate the two arch-shaped pieces forming a single core member.

The width of the strip of steel forming these pieces is half the width of the member used in the structure shown in Figs. 1 and 2. Three of the six pieces will have a butt joint surface cut along a line corresponding to the line 24 in Fig. 4, and the other three will have a face cut along the line 25 as shown in Fig. 4.

In the embodiment of the invention shown in Figs. 1, 2, 3 and 4, the material between the surfaces indicated by lines 24 and 25 in Fig. 4 is waste material. In the embodiment shown in Fig. 5, there will be no waste material since three of the six pieces require a butt joint surface corresponding to the direction of the line 24 and the other three of the six pieces require a butt joint surface corresponding to the direction of the line 25. In the loops from which the pieces used in Fig. 5 are cut a single cut only is required. This cut may be made either along the line 24 or along the line 25. Three complete loops, cut along the line 24 or along the line 25, will provide six pieces, or enough to form a complete core unit. It will be realized that when the core is made of these six pieces the six pieces are identical whether cut along the line 24 or the line 25. By turning a piece end for end the cut surface will correspond either to the slope of the line 24 or to the slope of the line 25. In the use of the six-piece core shown in Fig. 5, it may be desirable to provide an insulated copper damping lamination 43 shown in Fig. 6 between the two U-shaped members 41 and 42 in each of the three legs along the dividing line 26 to damp out cross-flux between the two members. Insulating strips 44 and 45 are provided between the damping lamination 43 and the core loop members 41 and 42.

The triangular shaped frame members 31 at the top and bottom of the core structure will differ from the member 15 in Figs. 1 and 2 in that provision will be made for six banding straps to be attached rather than three. The straps 32, 33 and 34 are shown attached by means of a screw portion 19 and nut 21 as are the bands in Fig. 1, and the remaining bands 35, 36 and 37 are shown as fastened by means of a clip 38 attaching the folded-over end portion of the band in a well known manner. Either of these attaching means, or any other suitable attaching means, may be employed.

Referring to Figs. 7, 8, 9 and 10, a core structure is formed similar in general principle to that shown in Figs. 1, 2, 3 and 4, but provided with a cruciform core section. In winding the core loop shown in Figs. 9 and 10, a certain number of turns 51 in the strip of sheet steel have a width 52, and other turns shown at 53 have a greater width 54, the final turns 55 also having the narrower width 52. The core loops are wound in a manner similar to the loops shown in Figs. 3 and 4 and are cut along planes indicated by the lines 56 and 57, the planes being at 120° with respect to each other, so that when three such core members are assembled as shown in Figs. 6 and 7, smooth cross-fitting butt joints will be provided along the planes indicated by lines 58—61, 58—62, 58—63, uniting the three arch-shaped core members 64, 65 and 66, shown in Figs. 7 and 8.

Before the three core members are assembled, the several coils comprising the winding sets associated with each core member are placed about the core member, thus rendering the assembly of the core and coil combination a relatively simple matter.

Modifications in the structure shown and illustrated may be made within the spirit of my invention, and I do not wish to be limited otherwise than by the scope of the appended claims.

I claim as my invention:

1. In a three-phase core structure for electrical induction apparatus, in combination, three arch-shaped core members each having a substantially straight winding leg portion forming the center of the arch and end portions at each end thereof extending at substantially right angles to the leg portion, each of the three members being formed of superimposed layers of magnetic sheet material bent flatwise to conform to the shape of the arch and bonded together by bonding material applied to the sheet of the magnetic material, the arch-shaped core members having faces worked on the end portions thereof along planes at such angles to the direction of the end portions that the faces on one member cooperate with similar faces of the two adjacent members to form low-loss butt joints adjacent the axis of the assembled structure, the three core members extending outwardly from the axis in directions displaced substantially 120° from each other, and means for holding the three core members in assembled position.

2. In a three-phase core structure for electrical induction apparatus, in combination, three arch-shaped core members each having a substantially straight winding leg portion forming the center of the arch and end portions at each end thereof extending at substantially right angles to the leg portion, each of the three arch-shaped core members being formed of superimposed layers of magnetic sheet material bent flatwise to conform to the shape of the arch and bonded together by bonding material applied to the sheet of the magnetic material, the arch-shaped core members having faces worked on the end portions thereof along planes at such angles to the direction of the end portions that the faces on one arch-shaped core member cooperate with similar faces of the two adjacent arch-shaped core members to form low-loss butt joints adjacent the axis of the assembled structure, the three arch-shaped core members extending outwardly from the axis in directions displaced substantially 120° from each other, each arch-shaped core member comprising two half-portions wound separately and divided along a plane passing through the axis of the assembled core member so that the two faces cooperating with similar faces on the two adjacent arch-shaped core members to form butt joints are, respectively, on the two half-portions, each in a plane passing through the axis of the core structure and displaced 60° from the plane dividing the two half-portions of the core member, and means for holding the several half-portions of the core members in assembled position.

3. In a three-phase core structure for electrical induction apparatus, in combination, three U-shaped core members having abutting joints at their opposite ends whereby each core member forms butt joints with both of the other two core members at both ends of the three members, each member having a straight winding leg portion forming the center of the arch and end portions at each end thereof extending at substantially right angles to the leg portions, each of the three members being formed of superimposed layers of sheet material bent flatwise to conform to the shape of the arch and bonded together by bonding material applied to the sheet material,

the several U-shaped core members each having faces worked on the end portions thereof along planes at such angles to the direction of the end portions that the faces on one U-shaped core member cooperate with similar faces of the two adjacent core members to form low-loss butt joints adjacent the axis of the assembled structure, the three U-shaped core members extending outwardly from the axis in directions displaced substantially 120° from each other, the plane of the several layers of sheet magnetic material adjacent the butt joints being substantially at right angles to the axis along which all three members meet, and means for holding the three core members in assembled position.

4. In a three-phase core structure for electrical induction apparatus, in combination, three U-shaped core members having abutting joints at their opposite ends whereby each of the three core members forms butt joints with each of the other two core members at both ends of the three core members, each member having a straight winding leg portion forming the center of the arch and end portions at each end thereof extending at substantially right angles to the leg portions, each of the three core members being members formed of superimposed layers of sheet material bent flatwise to conform to the shape of the arch and bonded together by bonding material applied to the sheet material, the U-shaped core members having faces worked on the end portions thereof along planes at such angles to the direction of the end portions that the faces on one core member cooperate with similar faces of the two adjacent core members to form low-loss butt joints adjacent the axis of the assembled structure, the three core members extending outwardly from the axis in directions displaced substantially 120° from each other, each core member comprising two half-portions wound separately and divided along a plane passing through the axis of the assembled core structure so that the two faces cooperating with the two adjacent core members to form butt joints are, respectively, on the two half-portions, each in a plane passing through the axis of the core structure and displaced 60° from the plane dividing the two

half-portions of the core member, the plane of the several layers of sheet magnetic material adjacent the butt joints being substantially at right angles to the axis along which all three members meet, and means for holding the three core members in assembled position.

5. In a three-phase core structure for electrical induction apparatus, in combination, three U-shaped core members having abutting joints at their opposite ends whereby each core member forms butt joints with both of the other two core members at both ends of three members, each member having a straight winding leg portion forming the center of the arch and end portions at each end thereof extending at substantially right angles to the leg portions, each of the three U-shaped core members being members formed of superimposed layers of sheet material bent flatwise to conform to the shape of the arch and bonded together by bonding material applied to the sheet material, the U-shaped core members having faces worked on the end portions thereof along planes at such angles to the direction of the end portions that the faces on one core member cooperate with similar faces of the two adjacent core members to form low-loss butt joints adjacent the axis of the assembled structure, the three core members extending outwardly from the axis in directions displaced substantially 120° from each other, each core member comprising two half-portions wound separately and divided along a plane passing through the axis of the assembled core structure so that the two faces cooperating with the two adjacent core members to form butt joints are, respectively, on the two half-portions, each in a plane passing through the axis of the core structure and displaced 60° from the plane dividing the two half-portions of the core member, and a sheet of electrically conducting material between the two half-portions of each U-shaped core member and insulated therefrom to provide a damping lamination for limiting the flow of magnetic flux between the two half-portions, and means for holding the several half-portions of the core members in assembled position.

LEWIS W. CHUBB.