July 13, 1965 C. E. BURKHARDT ETAL 3,195,090

MAGNETIC CORE STRUCTURES

Filed June 7, 1961 2 Sheets-Sheet 1

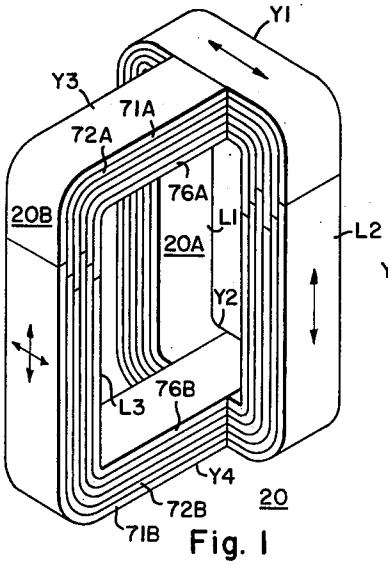


Fig. 1

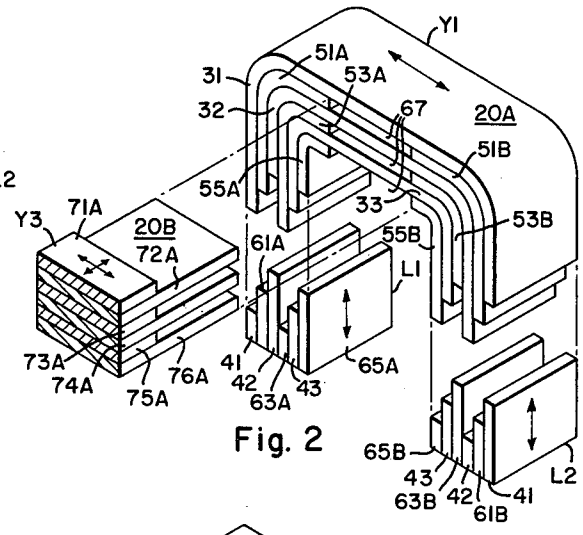


Fig. 2

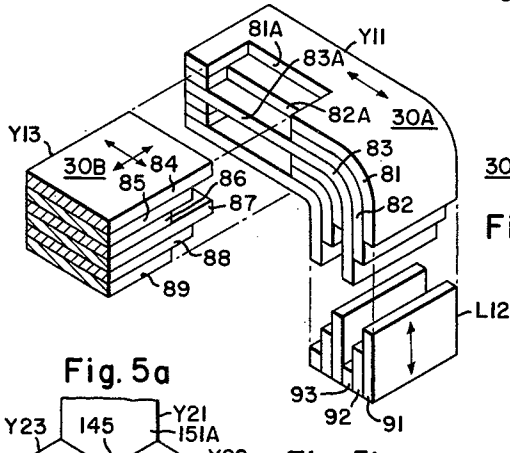


Fig. 3

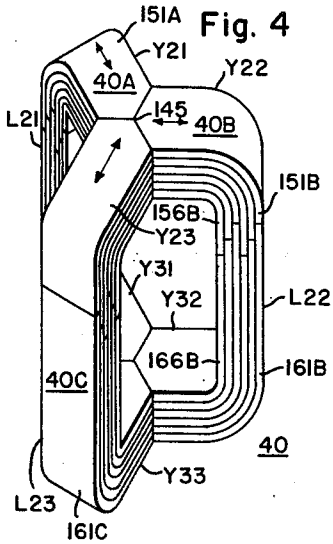


Fig. 4

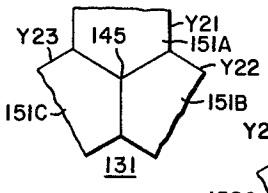


Fig. 5a

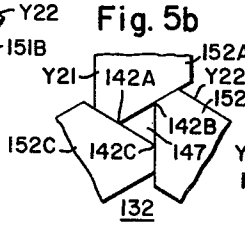


Fig. 5b

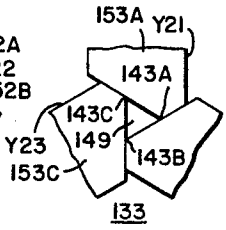


Fig. 5c

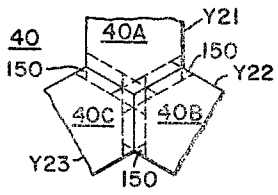


Fig. 6

WITNESSES

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MAGNETIC CORE STRUCTURES

Filed June 7, 1961 2 Sheets-Sheet 2

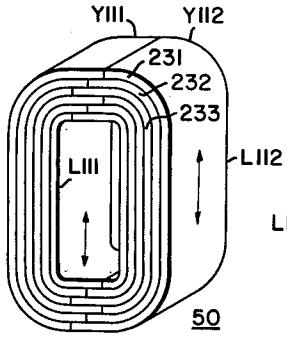


Fig. 8

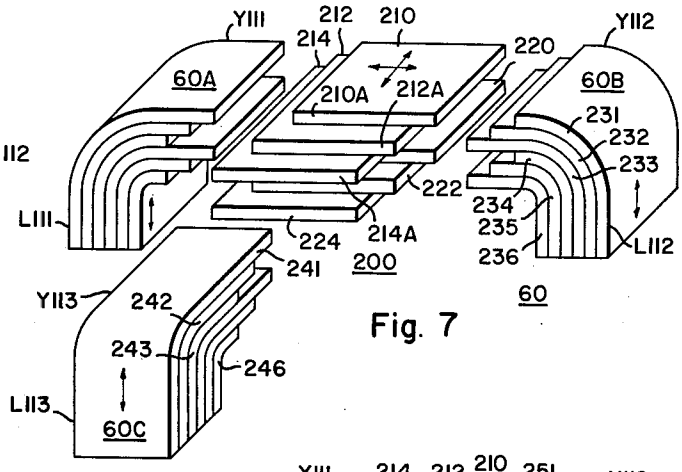


Fig. 7

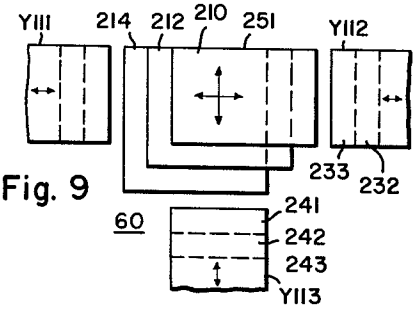


Fig. 9

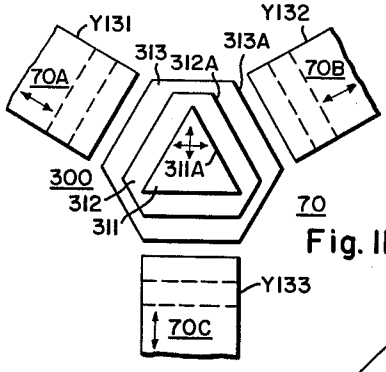


Fig. II

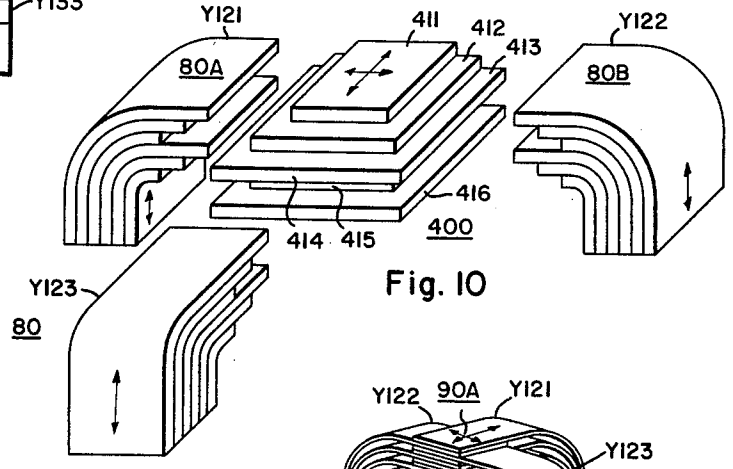


Fig. 10

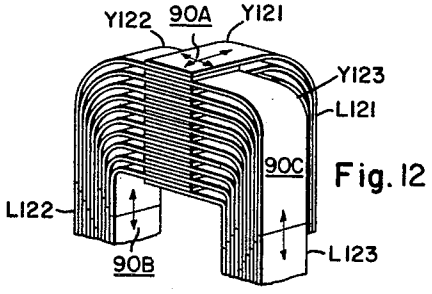


Fig. 12

United States Patent Office 3,195,090 Patented July 13, 1965

3,195,090

MAGNETIC CORE STRUCTURES

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Filed June 7, 1961, Ser. No. 115,336
13 Claims. (Cl. 336—218)

This invention relates to electrical inductive apparatus, such as transformers, and more particularly to magnetic core structures for such apparatus.

A number of different types of three-phase magnetic core structures for electrical inductive apparatus, such as transformers, have been developed in the past which include a plurality of laminations or punchings formed from magnetic strip or sheet material having a preferred direction of magnetic orientation or easier magnetization substantially parallel to its edges or longitudinal dimension, such as cold rolled silicon steel, and which are adapted to take advantage of the properties of such magnetic material. Each type of conventional three-phase magnetic core structure has certain limitations with respect to the losses in the magnetic core structure during the operation of the associated inductive apparatus, with respect to the length of the magnetic paths in the different portions of the magnetic core structure or with respect to the difficulty of manufacturing and assembling the magnetic core structure. In addition, magnetic sheet or strip materials have now been developed which have more than one preferred direction of magnetic orientation and which have lower loss characteristics than the singly oriented magnetic material just described, particularly at smaller thicknesses. For example, one type of doubly oriented magnetic strip material which has been developed has a first preferred direction of orientation substantially parallel to its edges or longitudinal dimensions and a second preferred direction of orientation substantially perpendicular or transverse to its edges or longitudinal dimension. It is therefore desirable to provide improved magnetic core structures which overcome one or more of the above limitations and which lend themselves to the utilization, at least in certain portions of the core structure, of magnetic strip material which has more than one preferred direction of magnetic orientation or which lend themselves to improved methods of manufacture and assembly.

It is an object of this invention to provide a new and improved three-phase magnetic core structure for electrical inductive apparatus, such as transformers.

Another object of this invention is to provide a new and improved magnetic core structure of the three-phase type employing at least in certain portions thereof magnetic sheet or strip material having more than one preferred direction of magnetic orientation.

A further object of this invention is to provide a three-phase magnetic core structure which lends itself to improved methods of manufacture and assembly.

Other objects of the invention will, in part, be obvious and will, in part, appear hereinafter.

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 drawing, in which:

FIGURE 1 is a view in perspective of a three-phase magnetic core structure embodying the teachings of the invention;

FIG. 2 is a detailed view illustrating in enlarged form certain of the joints of the magnetic core structure shown in FIG. 1;

FIG. 3 is an enlarged detailed view illustrating a modified joint structure which may be employed for certain of the joints in the magnetic core structure shown in FIG. 1;

FIG. 4 is a view in perspective of a three-phase magnetic core structure illustrating another embodiment of the invention;

FIGS. 5*a*, 5*b*, and 5*c* are partial top plan views of successive layers of laminations included in the magnetic core structure shown in FIG. 4;

FIG. 6 is a partial top plan view illustrating in enlarged form certain of the joints of the magnetic core structure shown in FIG. 4;

FIG. 7 is an enlarged detailed view in perspective of a portion of a three-phase magnetic core structure illustrating another embodiment of the invention;

FIG. 8 is a view in perspective of a magnetic core structure illustrating how different portions of the magnetic core structure shown in FIG. 7 may be formed;

FIG. 9 is a partial top plan view illustrating certain joints of the magnetic core structure shown in FIG. 7;

FIG. 10 is an enlarged detailed partial view in perspective illustrating a modified joint structure which may be employed in the magnetic core structure shown in FIG. 7;

FIG. 11 is a partial top plan view of a three-phase magnetic core structure illustrating another embodiment of the invention; and

FIG. 12 is a partial view in perspective of a three-phase magnetic core structure illustrating another embodiment of the invention.

Referring now to the drawings and FIGS. 1 and 2 in particular, there is illustrated a three-phase magnetic core 20 embodying the teachings of the invention. In general, the magnetic core 20 comprises a substantially rectangular closed loop member 20A and a half loop member or generally U-shaped member 20B. More specifically, the closed loop member 20A includes two opposite sides indicated at L1 and L2 which are disposed substantially in parallel with and spaced apart from one another to provide first and second winding leg portions, respectively, while the other two opposite sides Y1 and Y2 of the closed loop member 20A connect the ends of said leg portions and serve as upper and lower yoke portions, respectively. The half loop member 20B includes a substantially straight central portion, indicated at L3, which functions as a third winding leg portion and the upper and lower portions indicated at Y3 and Y4, respectively, which are disposed at substantially right angles with respect to said leg portion and which function as connecting upper and lower yoke portions, respectively.

As shown in FIG. 1, at each end of the magnetic core 20, one of the yoke portions Y3 and Y4 of the half loop member 20B is disposed at substantially a right angle with one of the assoicated yoke portions Y1 and Y2, respectively, of the closed loop member 20A to form respective joints therewith in the form of a T with the third leg portion L3 being disposed substantially parallel to and spaced from each of the first and second leg portions L1 and L2. In other words, if it is assumed that the closed loop member 20A defines a first plane and that the half loop member 20B defines a second plane, then the plane of the half loop member 20B is disposed at substantially a right angle or normal to the plane defined by the closed loop member 20A. It is to be noted that in an actual core and coil assembly, that associated electrical windings (not shown) would be disposed on each of the leg portions L1, L2 and L3 of the magnetic core 20.

In particular, the closed loop member 20A comprises a plurality of layers of laminations formed from magnetic strip or sheet material having a preferred direction of orientation substantially parallel to its edges or longitudinal dimension and assembled flatwise in nested or superposed relation. Although the invention will be de-

scribed and illustrated for the purpose of simplicity as if each layer of laminations is only one lamination thick, it is to be understood that in certain applications, as required, that each layer of laminations may include two or more laminations having the same general shape to make up an overall thickness of the layer. The alternate layers of the closed loop member 20A include first and second generally U-shaped laminations whose ends meet and are substantially aligned with each other in the first and second leg portions L1 and L2, as indicated at 31 and 41, at 32 and 42, and at 33 and 43, respectively for the first, third and fifth layers shown in FIG. 2. The intervening layers of laminations in the closed loop member 20A comprise first and second pairs of generally L-shaped laminations at the upper and lower ends of the closed loop member 20A as indicated at 51A and 51B and 61A and 61B, at 53A and 53B and 63A and 63B, and at 55A and 55B and 65A and 65B for the second, fourth and sixth layers of laminations, respectively, in FIG. 2. The ends of the generally L-shaped laminations in the intervening layers of the closed member 20A meet and are substantially aligned in the leg portions L1 and L2 of the closed loop member 20A, while the ends of the generally L-shaped laminations in the yoke portions Y1 and Y2 are spaced apart from one another to provide a plurality of substantially rectangular recesses or openings, as indicated at 67, for the upper end of the closed loop member 20A in alternate layers of laminations. It is to be understood that, in certain applications, a generally U-shaped lamination having a substantially rectangular recess therein which extends a predetermined distance across its width may be substituted for each pair of generally L-shaped laminations in the intervening layers in the upper and lower ends of the closed loop member 20A.

As illustrated in FIG. 2, the meeting ends of the generally U-shaped and L-shaped laminations which make up the closed loop member 20A in each layer of laminations are both cut substantially perpendicular or transverse to the edges thereof with the cut ends of the laminations in the successive adjacent layers being displaced or offset from one another by a predetermined distance. The latter distance should be more than 2.5 times the thickness of each lamination and preferably at least six times the thickness of each lamination so that the joints between the meeting ends of the laminations in each layer of the leg portions L1 and L2 of the closed loop member 20A are overlapped by the laminations in the adjacent layers to form a series of stepped-lap joints in each of said leg portions and to derive the benefits of the disclosed core structures. In certain applications, it is to be undestood that the meeting ends of the laminations in the leg portion L1 and L2 may be each cut at a predetermined oblique angle with respect to the edges of the laminations and with the ends of successive layers in each group being offset from and substantially parallel to each other. It is to be noted that the meeting ends of the laminations in each of the leg portions L1 and L2 are arranged in groups with a series of stepped-lap joints in each group in a repeating or recurring pattern. It is to be noted that each group should include more than three laminations or preferably at least a thickness of six laminations before a new group is started and a pattern of stepped-lap joints repeated in order to obtain the benefits of the disclosed magnetic core structure. The stepped-lap joints provided in each of the leg portions L1 and L2 of the closed loop member 20A are provided in order to facilitate convenient assembly of associated electrical windings on each of said leg portions in a core and coil assembly and to reduce the exciting current and losses compared with conventional alternate butt-lap or butt joints.

Similarly the half loop member 20B includes a plurality of layers of laminations formed from magnetic strip or sheet material having a preferred direction of magnetic orientation substantially parallel to its edges or longitudinal dimensions, such as cold rolled silicon steel, and assembled flatwise in nested or superposed relation to form a substantially straight third leg portion L3 and the connecting yoke portions Y3 and Y4 at the upper and lower ends, respectively of said leg portion. Each layer of laminations of the half loop member 20B includes at least first and second generally L-shaped laminations whose ends meet in the third leg portion L3 with the meeting ends in said leg portion being substantially aligned with each other. For example, as shown in FIGS. 1 and 2, the six layers of laminations which make up the half loop member 20B include the first laminations 71A through 76A and the associated second laminations 71B through 76B, respectively. The meeting ends of the L-shaped laminations in the leg portion L3 of the half loop member 20B are cut substantially perpendicular or transverse with respect to the edges thereof and displaced or offset from the cut ends of the laminations in the adjacent layers similarly to the joints between the meeting ends of the laminations in the leg portions L1 and L2 of the closed loop member 20A to form a series of stepped-lap joints arranged in recurring or repeating groups as previously described in greater detail in connection with the closed loop member 20A. The other ends of the L-shaped laminations 71A through 76A and 71B through 76B which make up the half loop member 20B in the upper and lower yoke portions Y3 and Y4, respectively, are also cut substantially perpendicular or transverse with respect to the edges thereof with the ends of alternate layers of laminations being cut shorter or offset from the ends of the adjacent laminations as shown in FIG. 2 by a predetermined distance which is substantially equal to the width of the laminations which make up the closed loop member 20A. The ends of the longer L-shaped laminations at each end of the half loop member 20B are then assembled or disposed in the associated recesses of the upper or lower yoke portions Y1 and Y2, respectively, of the closed loop member 20A, as indicated at the ends of the laminations 72A, 74A and 76A at the upper end of the half loop member 20B, which are disposed in the substantially rectangular recesses 67 in the yoke portion Y1 between the associated layers of generally L-shaped laminations 51A and 51B, 53A and 53B, and 55A and 55B, respectively, with the ends of the intervening laminations 71A, 73A and 75A of the half loop member 20B disposed to abut against the sides of the generally U-shaped laminations 31, 32 and 33 of the closed loop member 20A to form a series of butt-lap joints at each end of the magnetic core 20. If generally U-shaped laminations are substituted for the pairs of generally L-shaped laminations in the closed loop member 20A as previously mentioned, the differences in length of the alternate layers of laminations in the half loop member 20B can be adjusted correspondingly in accordance with the steps of the substantially rectangular recesses provided in such modified U-shaped laminations. It is to be noted that the stepped-lap joints in each of the groups of generally L-shaped laminations which make up the half loop member 20B are provided in order to facilitate the assembly of the magnetic core 20 with an associated electrical winding on the third winding leg portion L3 of said magnetic core.

Referring to FIG. 3, there is illustrated a three-phase magnetic core 30 which is similar to the magnetic core 20 previously described except that the joints between the yoke portions of the closed loop member 30A and the half loop member 30B of the magnetic core 30 include a series of stepped-lap joints arranged in groups similarly to the joints between the laminations in the leg portions L1, L2 and L3 of the magnetic core 20. More specifically, each layer of laminations of the closed loop member 30A of the magnetic core 30 includes at least first and second generally U-shaped laminations whose ends meet and are substantially aligned in the first and second leg portions thus formed as indicated at 81 and 91, at 82 and

92, and at 83 and 93 for the first, second and third layers of laminations, respectively, whose ends meet at each side of the magnetic core 30 as shown for the leg portion L12 in FIG. 3. The meeting ends of the generally U-shaped laminations in the closed loop member 30A are arranged to form a series of stepped-lap joints in each group of repeating or recurring laminations similarly to the stepped-lap joints in the leg portions of the magnetic core 20 previously described in greater detail. At least the majority of the generally U-shaped laminations which make up the closed loop member 30A include a substantially rectangular recess or opening located centrally of the yoke portion at either end of said closed loop member as indicated at 81A and 82A for the U-shaped laminations 81 and 82, respectively, in the yoke portion Y11. The depth of the substantially rectangular recesses in the U-shaped laminations which make up the closed member 30A at each end of the magnetic core 30 are offset from each other with the depth of the recess in certain laminations being substantially negligible or the recess being absent as indicated at 83A in the lamination 83 in FIG. 3 and with the recesses in successive layers of laminations being arranged in a stepped pattern which is recurring or repeating in groups of layers. The half loop member 30B included in the magnetic core 30 also includes a plurality of layers of laminations formed from magnetic strip material having a preferred direction of orientation substantially parallel to its edges or longitudinal dimension and assembled flatwise in nested or superposed relation with the ends of successive layers of laminations in the yoke portion Y13 of the half loop member 30B being cut substantially perpendicular or transverse with respect to the edges thereof. The cut ends of the generally L-shaped laminations 84 through 89, which make up the half loop member 30B, in the yoke portions thereof are offset or displaced from one another in a stepped pattern which matches or corresponds to the recesses in the associated yoke portions of the closed loop member 30A of the magnetic core 30. The half loop member 30B is then assembled with the stepped ends of the L-shaped laminations 84 through 89 as indicated for the yoke portion Y13 disposed either in the substantially rectangular recesses as indicated at 81A and 82A of the laminations 81 and 82, respectively, which make up the yoke portion Y11 of the closed loop member 30A or in abutting aligned relation with the sides of certain laminations, as indicated at 83, to provide a series of stepped-lap joints in which the amount of overlap is at least six times the thickness of each lamination and with at least six laminations across the thickness of each recurring or repeating group. It is to be noted that certain of the L-shaped laminations of the half loop member 30B, such as the lamination 86, are disposed to abut against the side of certain laminations such as the lamination 83 of the closed loop member 30A which do not include any recesses. It is to be understood that the half loop member 30B of the magnetic core 30 may include a series of stepped-lap joints in repeating or recurring groups in the leg portion thereof, similarly to the leg portions L1, L2 and L3 of the magnetic core 20 or that the latter joints in the leg portion of the half loop member 30B may be omitted in certain applications.

It is to be understood that in certain applications that the laminations which make up the half loop members 20B and 30B of the magnetic cores 20 and 30, respectively, may be formed from a magnetic strip or sheet material having a first preferred direction of magnetic orientation substantially parallel to its edges or longitudinal dimension and having a second preferred direction of magnetic orientation substantially transverse or perpendicular to said first direction of orientation in order to improve the magnetic performance of said magnetic cores. It is important to note that in the latter modified constructions that the second preferred direction of orientation of the magnetic strip material from which the laminations of the half loop members 20B and 30B are formed would substantially coincide with the single preferred direction of orientation of the magnetic strip material from which the laminations of the closed loop members 20A and 30A are formed to thereby reduce the overall reluctance of the magnetic cores 20 and 30 and improve the magnetic flux transfer between the half loop members 20B and 30B and the associated closed loop members 20A and 30A, respectively.

Examples of suitable types of magnetic material from which the laminations of the half loop members 20B and 30B may be formed in the modified construction just described include sheets of silicon-iron and aluminum-iron alloys containing from 1 to 7% silicon, and 1 to 10% aluminum, respectively. The sheets of said alloys have grains whose crystal lattice structure comprises four cube edges substantially perpendicular to the plane of the sheet, known as cube texture which may be either doubly oriented or randomly oriented. The major volumetric proportion of the sheets is composed of grains having a crystalline lattice structure such that a cube face lies substantially parallel to the surface of the sheet and in the doubly oriented material, four cube edges of the cube lattice are parallel to the rolling direction or edge of the sheet and four cube edges are transverse thereto. In the randomly oriented cube texture material, the grains may have eight cube edges randomly distributed parallel to the surface of the sheet. One such doubly oriented cube textured silicon-iron alloy is that disclosed in copending application Serial No. 681,333 filed August 30, 1957, and now abandoned, and in copending application Serial No. 19,440, filed April 21, 1960, now Patent No. 2,992,951, which are both assigned to the same assignee as the present application.

Suitable arrows are disposed on the various magnetic core sections throughout the drawings to indicate singly oriented material and cube texture, doubly and randomly oriented.

Referring now to FIGS. 4 through 6, there is illustrated another three-phase magnetic core 40 embodying the teachings of the invention. In general, the magnetic core 40 comprises three half loop members or generally U-shaped members 40A, 40B and 40C each having a substantially straight central portion to provide a winding leg portion as indicated at L21, L22 and L23, respectively, and first and second connecting yoke portions disposed at substantially right angles with respect to the associated winding leg portions, as indicated at Y21 and Y31, at Y22 and Y32, and at Y23 and Y33, respectively, in FIG. 4. The three generally U-shaped core members 40A, 40B and 40C are assembled or disposed around a common longitudinal axis, as indicated at 145, in a substantially symmetrical arrangement with the yoke portions of the respective core members meeting in common joints at each end of said core and extending outwardly from said central axis in directions which are displaced from one another by substantially equal angles of 120° with respect to said central axis.

More specifically, each of the generally U-shaped core members 40A, 40B and 40C of the magnetic core 40 comprises a plurality of layers of laminations or punchings formed from magnetic sheet or strip material having at least one preferred direction of magnetic orientation substantially parallel to its edges or longitudinal dimension and assembled flatwise in nested or superposed relation to form the central winding leg portion and the connecting yoke portions at the opposite ends thereof. In particular, each of the layers of laminations of each of the core members 40A, 40B and 40C includes first and second generally L-shaped laminations as indicated at 151B and 161B through 156B and 166B, respectively, for the core member 40B in FIG. 4 with the meeting ends of the generally L-shaped laminations in each layer of laminations being substantially aligned with each other in the leg portion of each core member and offset or

displaced from the meeting ends of the laminations in the adjacent layers by a predetermined distance which is at least six times the thickness of each lamination to form a series of stepped-lap joints which are arranged in recurring or repeating groups as previously described in greater detail for the leg portions of each of the magnetic cores 20 and 30.

The ends of the laminations which make up each of the core members 40A, 40B and 40C and which meet in each of the overall yoke portions of the magnetic core 40 are substantially aligned with the ends of the laminations in the corresponding layers of the other core members. The meeting ends of the corresponding layers of laminations in the yoke portions at each end of the core members 40A, 40B and 40C are cut to be generally V-shaped in configuration as best shown in FIGS. 5*a*, 5*b* and 5*c* which illustrate the successive layers of laminations 131, 132 and 133 in the upper yoke portions Y21, Y22 and Y23 of the core members 40A, 40B and 40C, respectively. As shown in FIGS. 5*a* through 5*c*, both sides of the V-shaped ends of each of the laminations which make up the core members 40A, 40B and 40C are cut at substantially a predetermined angle, preferably an angle of substantially 60°, with respect to the edges or longitudinal dimension of the strip material from which said laminations are formed. It is to be noted that the tips or apexes of the V-shaped ends of the corresponding laminations in successive layers which meet in the yoke portions at each end of the magnetic core 40 are laterally offset or displaced from one another with respect to the center line of each of the corresponding laminations along a line which is substantially perpendicular to said center line and passes through the longitudinal axis, indicated at 145, by a distance which is at least six times the thickness of each of the laminations in order that the joints between the meeting ends of the corresponding layers of laminations in the core members 40A, 40B and 40C be overlapped by the adjacent layers of laminations and to produce a series of stepped-lap joints between the yoke portion of each of the core members 40A, 40B and 40C and those of the other respective core members at each end of the magnetic core 40. For example, the apexes of the V-shaped ends of the laminations 151A, 152A, 153A of the layers 131, 132 and 133, respectively, as shown in FIGS. 5*a* through 5*c*, respectively, are laterally displaced with respect to a common centerline of each of the corresponding laminations, as indicated at 145, 142A and 143A, respectively. Similarly the apexes of the V-shaped ends of the laminations 151B, 152B and 153B are arranged in a stepped pattern and laterally displaced from one another as indicated at 145, 142B and 143B, respectively, while the tips or apexes of the V-shaped ends of the laminations 151C, 152C and 153C are similarly arranged as indicated at 145, 142C and 143C, respectively. It is to be noted that in the layer of laminations shown in FIG. 5*a* that when the V-shaped ends of the laminations 151A, 151C and 151B are symmetrically arranged with respect to the center lines through the respective laminations, then the apexes of the V-shaped ends of the laminations in the layer 131 meet substantially at the central longitudinal axis of the magnetic core 40, as indicated at 145. When, however, the V-shaped ends of a meeting lamination in the other layers 132 and 133 shown in FIGS. 5*b* and 5*c* respectively are not symmetrical with respect to the center lines through the respective laminations in each of said layers, then the apexes of the V-shaped ends of the meeting laminations are displaced from one another by predetermined distances so that a hole or opening results centrally in the yoke portions of the magnetic core 40 as indicated at 147 and 149 for the layers 132 and 133, respectively. As best shown in FIG. 6, it should also be noted that when the sides of the V-shaped ends of the meeting laminations in certain layers are not symmetrical with respect to the center lines in the respective laminations as in the layers 132 and 133, then substantially triangular recesses result in the outer portion of the overall joint between the meeting yoke portions of the respective core members 40A, 40B and 40C, as indicated at 150 in FIG. 6. As mentioned previously and as best shown in FIG. 6, the joints between the corresponding layers of laminations in the yoke portions of the core members 40A, 40B and 40C are all substantially symmetrical with respect to the central longitudinal axis of the magnetic core 40, as indicated at 145 in FIG. 6.

The stepped-lap joints in each group of layers of laminations in each of the leg portions L21, L22 and L23 of the magnetic core 40 are provided in order to facilitate the assembly of the magnetic core 40 with associated preformed electrical windings which are disposed on each of said leg portions, but it is to be understood that the stepped-lap joints in the leg portions L21, L22 and L23 of the magnetic core 40 may be omitted in certain applications in which the openable joints between the yoke portions of the core members 40A, 40B and 40C would be relied on to facilitate the assembly of electrical windings on the leg portions of the respective core members. In the latter modified construction, each of the core members 40A, 40B and 40C would include a plurality of layers of generally U-shaped laminations rather than each of said layers including at least first and second generally L-shaped laminations as shown in FIG. 4. In the latter construction, the V-shaped ends of the laminations in the yoke portions of each of the core members 40A, 40B and 40C would be arranged as just described in detail to provide a series of stepped-lap joints in recurring or repeating groups in said yoke portions between the respective core members.

It is important to note that the apexes of the V-shaped ends of the corresponding laminations in successive layers in each of the core members 40A, 40B and 40C of the magnetic core 40 are laterally displaced from one another along a line which is substantially perpendicular or transverse with respect to the center line of the respective corresponding laminations and which passes substantially through the central longitudinal axis of the magnetic core 40, as indicated at 145.

Referring now to FIGS. 7 through 9, there is shown a three-phase magnetic core illustrating another embodiment of the invention. In general, the three-phase magnetic core 60 comprises three half loop members or generally U-shaped members 60A, 60B and 60C and first and second magnetic insert members 200 which each include a plurality of magnetic insert laminations 210 through 224, at the opposite ends of the magnetic core 60, as shown in FIG. 7. The core members 60A, 60B and 60C include the substantially straight central portions L111, L112 and L113 to provide winding leg portions and connecting yoke portions at the opposite ends thereof, as indicated at Y111, Y112 and Y113, respectively, at the upper ends of said core members, which are disposed at substantially right angles with respect to the associated winding leg portions. The core members 60A and 60B are assembled or disposed with the yoke portions thereof facing each other and with the magnetic insert members 200 disposed between the yoke portions of said core members at each end of the magnetic core 60 to form a substantially closed loop magnetic member having a substantially rectangular configuration. If it is assumed that the substantially closed magnetic loop member just described defines a first plane, then the third core member 60C is assembled to form a joint with the magnetic insert members 200 at the opposite ends of the magnetic core 60 with the plane defined by the core member 60C being disposed at substantially a right angle or normal with respect to the plane defined by the closed magnetic loop member previously described.

More specifically, each of the core members 60A, 60B and 60C comprises a plurality of laminations or punchings

formed from a magnetic strip material having a preferred direction of orientation substantially parallel to its edges or longitudinal dimension and assembled flatwise in nested or superposed relation to provide a substantially straight winding leg portion as indicated at L111, L112 and L113, respectively, and the connecting yoke portions at the opposite ends thereof as previously mentioned. For example, the core member 60B comprises a plurality of generally U-shaped laminations 231 through 236, while the core member 60C comprises a plurality of generally U-shaped laminations 241 through 246, as indicated in FIG. 7. The ends of the laminations which make up each of the core members 60A, 60B and 60C are cut substantially perpendicular transverse with respect to the edges thereof with the cut ends of the laminations in successive layers of laminations being offset or displaced from one another by a predetermined distance which is at least six times the thickness of each lamination to form a plurality of groups of layers of laminations with the ends of the laminations being arranged in a stepped pattern. As shown in FIG. 8, the core members 60A, 60B and 60C may be conveniently formed in pairs by winding a plurality of turns of magnetic strip or sheet material on an associated mandrel (not shown) and arranging the meeting ends of successive layers of laminations to be substantially aligned with each other and offset or displaced from one another to form a series of stepped-lap joints in the magnetic core structure 50 at each end of said magnetic core which may then be opened to provide two of the three magnetic core members required to make up the magnetic core 60 shown in FIGS. 7 and 9.

As previously indicated, the magnetic insert member 200 includes a plurality of substantially rectangular laminations or punchings formed from magnetic strip material having a first preferred direction of orientation substantially parallel to its edges or longitudinal dimension and a second preferred direction of orientation which is substantially perpendicular or transverse with respect to the first direction of orientation. In particular, the magnetic insert member 200 which is provided at each end of the magnetic core 60 includes a plurality of substantially rectangular laminations 210 through 224 with at least three sides of each substantially rectangular insert lamination being displaced from the corresponding sides of the adjacent layers of laminations to provide a stepped pattern on at least three sides of the insert laminations 210 through 224 with the stepped pattern being arranged in recurring or repeating groups to match the stepped patterns in the ends of the yoke portions of the core members 60A, 60B which are assembled on the latter three sides of the insert laminations 210 through 224. The joints between the insert laminations 210 through 224 and the meeting ends of associated laminations in the yoke portions of the core members 60A, 60B and 60C are overlapped by the adjacent layers of laminations to form a series of stepped-lap joints in repeating or recurring groups between the magnetic insert members 200 and each of the core members 60A, 60B and 60C at each end of the magnetic core 60. It is to be noted, as shown in FIG. 9, that the length of the sides of the insert laminations 210 through 224 which are substantially parallel to the plane defined by the closed loop which includes the core members 60A and 60B on opposite sides of said insert laminations and the magnetic insert members 200 remains at substantially a predetermined value while the transverse dimension of said insert laminations which is substantially normal to the plane defined by the latter closed loop or substantially parallel to the plane defined by the third core member 60C varies in a stepped pattern with the side of the insert laminations on which the third core member 60C is disposed forming a stepped sequence in which the sides of successive layers of insert laminations are displaced from those in the adjacent layer by a predetermined distance which is at least six times the thickness of the laminations which make up the magnetic insert member 200. It is important to note that the first preferred direction of orientation of the magnetic strip material from which the insert laminations 210 through 224 are formed is substantially coincident with the preferred direction of orientation of the magnetic strip material from which the laminations of each of the core members 60A and 60B are formed while the second preferred direction of orientation of the magnetic strip material from which the insert laminations 210 through 224 are formed is substantially coincident with the preferred direction of orientation of the magnetic strip material from which the laminations of the preferred core members 60C are formed to thereby reduce the overall reluctance of the magnetic core 60 and to improve the transfer of magnetic flux between the third core member 60C and each of the core members 60A and 60B in the different magnetic paths provided in the magnetic core 60. It is to be noted that the slopes of the stepped-lap joints formed between the groups of laminations which make up each of the core members 60A and 60B of the magnetic core 60 and the insert laminations of the magnetic insert members 200 are substantially parallel with one another on the opposite sides of said magnetic insert member.

It is to be understood that stepped-lap joints may be added to the leg portions of each of the core members 60A, 60B and 60C in a particular application similarly to the stepped-lap joints provided in the different magnetic cores previously described in detail, but it is preferred that the stepped-lap joints provided between the magnetic insert member 200 and each of the core members 60A, 60B and 60C be disposed near the corner of each of said core members in order to eliminate the latter additional requirement for joints in the leg portions of said core members and to facilitate the assembly of the core members 60A, 60B and 60C with associated preformed electrical windings which would be disposed on the winding leg portions of said core members.

Referring now to FIG. 10, there is illustrated a three-phase magnetic core 80 which is similar to the magnetic core 60 just described except that the construction of the magnetic insert members between the different core members included in the magnetic core 80 has been modified. Similarly to the magnetic core 60, the magnetic core 80 includes three half loop members or generally U-shaped core members 80A, 80B and 80C which are similar to the core members 60A and 60C of the magnetic core 60 previously described in detail. The magnetic insert members 400 are similar to the magnetic insert members 200 except that the dimensions of the substantially rectangular insert laminations 411 through 416 vary in steps in both directions. In particular, the dimensions of the insert laminations 411 through 416 vary in steps in a first direction which is substantially parallel to the plane defined by the closed loop which includes the core members 80A and 80B and the magnetic insert members 400, and in a second direction which is substantially perpendicular or normal to the latter plane or substantially parallel to the plane defined by the third core member 80C in order to provide a series of stepped-lap joints between the magnetic insert members 400 and each of the core members 80A, 80B and 80C. It is to be noted that the insert laminations which make up the insert magnetic member 400 are arranged with at least three corresponding sides of the successive layers of laminations arranged in a stepped pattern and that the slopes of the stepped-lap joints formed between said magnetic insert members and the core members 80A and 80B on opposite sides of said magnetic insert member are not disposed substantially parallel to one another, as in the magnetic core 60, but that the slopes of the stepped-lap joints between the magnetic insert members 400 and the core members 80A and 80B are disposed in substantially oppo-

site directions with respect to one another. It is important to note that in the magnetic core 80, as in the magnetic core 60, that the first preferred direction of orientation of the magnetic strip material from which the insert laminations 411 through 416 are formed is substantially coincident with the preferred direction of orientation of the magnetic strip material from which the layers of laminations of the core members 80A and 80B are formed, while the second preferred direction of orientation of the magnetic strip material from which the insert laminations 411 through 416 are formed is substantially coincident with the preferred direction of orientation of the magnetic strip material from which the layers of laminations of the third core members 80C are formed. It is to be noted that the proper matching of the meeting ends of the laminations of each of the yoke portions Y121, Y122, and Y123 of the core members 80A, 80B and 80C, respectively, to the stepped pattern in the repeating or recurring groups of the insert laminations of the magnetic insert member 400 may be obtained from the magnetic core structure 50 shown in FIG. 8 by turning the half loop members end to end as required for the assembly of the magnetic core 80 in FIG. 10.

Referring to FIG. 11, there is shown a three-phase magnetic core 70 illustrating another emobdiment of the invention. In general, the magnetic core 70 includes three half loop members or generally U-shaped members 70A, 70B and 70C and the first and second magnetic insert members 300, similarly to the magnetic core 60 previously described. Each of the core members 70A, 70B and 70C is the same as the core members 60A and 60C of the magnetic core 60 and includes a substantially straight central winding leg portion and connecting yoke portions at the opposite ends thereof as indicated at Y131, Y132 and Y133 at the upper ends of the core members 70A, 70B and 70C, respectively, in FIG. 11. The magnetic insert members 300 each includes a plurality of layers of laminations, such as the insert lamination 311, which is substantially triangular in configuration, and the insert laminations 312 and 313 which are substantially hexagonal in configuration, said laminations being formed from a magnetic strip material having a random orientation of the type previously mentioned and having more than one preferred direction of magnetic orientation. At least three corresponding sides of the successive layers of laminations 311 through 313 of the magnetic insert members 300 are arranged offset or displaced from one another in a stepped pattern to match the meeting ends of the layers of laminations in each of the core members 70A, 70B and 70C with the corresponding layers of laminations being substantially aligned with each other and the joints between the meeting laminations being overlapped by those in the adjacent layers of laminations to form a series of stepped-lap joints between the magnetic insert members 300 and each of the core members 70A, 70B and 70C in groups which are recurring or repeating. The core members 70A, 70B and 70C of the magnetic core 70 are symmetrically arranged around a central axis which extends longitudinally through the magnetic core 70 with the yoke portions of said core members extending outwardly from said central axis and being displaced from one another by substantially predetermined angles of 120° with respect to said central axis similarly to the magnetic core 40 previously described. The randomly oriented magnetic strip material from which the insert laminations of the magnetic insert members 300 are formed includes preferred directions of orientation which coincide with the respective preferred directions of orientation of the magnetic strip materials from which the laminations of each of the core members 70A, 70B and 70C are formed to reduce the overall reluctance of the magnetic core 70 and improve the transfer of magnetic flux between said core members and said magnetic insert members at each end of the magnetic core 70, in the different magnetic paths divided in said magnetic core.

It is to be understood that the laminations of the magnetic insert members 300 may also be formed from doubly oriented magnetic material with one preferred direction of orientation of the strip material from which the successive layers are formed being rotated substantially 120° in a plane which is substantially normal to the central axis of the core 70 about said central axis to balance the reluctances between the insert members 300 and each of the core members 70A, 70B and 70C.

Referring now to FIG. 12 there is shown a three-phase magnetic core 90 illustrating another embodiment of the teachings of the invention. In general, the magnetic core 90 includes three half loop members or generally U-shaped members 90A, 90B and 90C, each having a substantially straight portion to provide a winding leg portion as indicated at L121, L122 and L123, respectively, and connecting yoke portions at each end thereof, as indicated at Y121, Y122 and Y123, respectively, at the upper end of the magnetic core 90 which are disposed at substantially right angles with respect to the associated winding leg portions. Each of the core members 90A, 90B and 90C includes a plurality of layers of laminations formed from magnetic strip or sheet material having a preferred direction of orientation substantially parallel to its edges or longitudinal dimension and assembled or disposed flatwise in nested or superposed relationship. Each of the layers or laminations of the core members 90A, 90B and 90C includes at least first and second generally L-shaped laminations having the ends cut in a stepped pattern in the leg portions L121, L122, and L123 to form a series of stepped-lap joints in each of said leg portions similarly to the magnetic cores 20 and 30 previously described in greater detail. The ends of the laminations in the yoke portions of the core members 90A, 90B and 90C at each end of the magnetic core 90 are progressively interleaved and overlap in sequence to provide a series of lap joints between the yoke portions of the core members 90A, 90B and 90C at each end of the magnetic core 90. It is to be noted that the thickness of the joints between the yoke portions of the core members 90A, 90B and 90C at each end of the magnetic core 90 is substantially three times the thickness of each of the leg portions L121, L122 and L123. The magnetic strip material from which the laminations of the core member 90A are formed also includes a second preferred direction of magnetic orientation substantially perpendicular transverse with respect to the edges or the first direction of orientation previously mentioned. This is because the core member 90A is disposed with the yoke portions of said core member disposed at substantially right angles with respect to the yoke portions of each of the core members 90B or 90C. In other words, if it is assumed that the core members 90B and 90C taken together define a first plane, then the third core member 90A is disposed with the plane defined by said third core member disposed at substantially a right angle with respect to the plane defined by the core members 90B and 90C. The first preferred direction of orientation of the magnetic strip material from which the laminations of the core member 90A are formed is disposed at substantially a right angle with respect to the preferred direction of orientation of the magnetic strip material from which the laminations of the core members 90B and 90C are formed but the second preferred direction of orientation of magnetic strip material from which the laminations of the core member 90A are formed substantially coincides or is parallel with the preferred direction of orientation of the magnetic strip material from which the laminations of the core members 90B and 90C are formed to reduce the overall reluctance of the magnetic core 90, reduce its losses and improve the transfer of magnetic flux between the third core member 90A and the first and second core members 90B and 90C, respectively, in the different magnetic paths provided in the magnetic core 90. It is to be understood, that the latter construction may be adapted to other types of three-legged cores wherever there is one

leg member whose laminations extend into or form lap joints with the other two leg members and where flux must travel in a direction which would result in high losses with the use of only singly oriented material.

The apparatus embodying the teachings of this invention have several advantages. For example, the different three-phase magnetic core structures disclosed offer the advantages of lower reluctance, lower losses and greater efficiency in the associated electrical apparatus and lend themselves to improved methods of manufacture and assembly. In addition, the magnetic core structures disclosed which include portions formed from laminations of magnetic strip material having more than one preferred direction of orientation are adapted to take advantage of the unique properties of such improved magnetic materials, while still utilizing the special advantages of singly oriented magnetic sheet or strip material in the other portions of the magnetic core structures disclosed.

It is understood that in the different magnetic cores disclosed that the slopes of the stepped-lap joints formed in successive groups may be arranged to be substantially parallel in a repeating or recurring pattern or that the slopes of the stepped-lap joints in successive groups may be oppositely disposed to form a generally sawtooth pattern in the overall joint.

Since numerous changes may be made in the above-described apparatus and different embodiments of the invention may be made without departing from the spirit and scope thereof, it is intended that all the matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

We claim as our invention:

1. A three-phase magnetic core comprising a substantially rectangular closed loop member including a plurality of layers of laminations formed from magnetic strip material and assembled in nested relationship, two parallel sides of said rectangular loop member forming first and second leg portions of said core and the other parallel sides forming yoke portions connecting said leg portions, alternate layers of laminations in each of said yoke portions including recesses therein, and a half loop member including a plurality of layers of laminations formed from magnetic strip material having at least two preferred direction of magnetic orientation and assembled in superposed relation to form a substantially straight third leg portion and connecting yoke portions at substantially right angles to the third leg portion, the yoke portions of said half loop member being disposed at substantially a right angle with respect to said closed loop member with the ends of alternate layers of laminations in the yoke portions of said half loop member being disposed in the recesses of the yoke portions of said closed loop member to form a series of butt-lap joints with the laminations of said closed loop member.

2. A three-phase magnetic core comprising a substantially rectangular closed loop member including a plurality of layers of laminations formed from magnetic strip material and assembled in nested relationship, two parallel sides of said rectangular loop member forming first and second leg portions of said core and the other parallel sides forming yoke portions connecting said leg portions, alternate layers of laminations in each of said yoke portions including recesses therein, and a half loop member including a plurality of layers of laminations formed from magnetic strip material having at least two preferred directions of magnetic orientation and assembled in superposed relation to form a substantially straight third leg portion and connecting yoke portions at substantially right angles to the third leg portion, the yoke, portions of said half loop member being disposed at substantially at right angle with respect to said closed loop member with the ends of alternate layers of laminations in the yoke portions of said half loop member being disposed in the recesses of the yoke portions of said closed loop member to form a series of butt-lap joints with the laminations of said closed loop member, the ends of the layers of laminations of each of said leg portions being cut substantially perpendicular to longitudinal edges of the laminations and assembled with the cut ends of the laminations of each layer substantially aligned and dispatched from those in the adjacent layers to form a series of stepped-lap joints.

3. A three-phase magnetic core comprising a substantially rectangular closed loop member including a plurality of layers of laminations formed from magnetic strip material having a preferred direction of orientation substantially parallel to longitudinal edges of the strip material and assembled flatwise in nested relation, two parallel sides of said rectangular loop member forming first and second leg portions and the other parallel sides forming first and second yoke portions connecting said first and second leg portions, alternate layers of laminations of said loop member each comprising first and second generally U-shaped laminations disposed at the first and second yoke portions of said core, respectively, with the ends of each of said first and second U-shaped laminations extending into said first and second leg portions and meeting to form butt joints, the layers of laminations intervening said layers of U-shaped laminations each comprising four generally L-shaped laminations disposed with certain ends of two of the L-shaped laminations butting against each other in said first leg portion, and certain ends of the remaining two L-shaped laminations butting against each other in said second leg portion, the remaining ends of said L-shaped laminations extending into said first and second yoke portions and spaced from each other to form recesses therein, and a generally U-shaped core member including a plurality of layers of generally L-shaped laminations formed from magnetic strip material having at least two preferred directions of magnetic orientation and assembled flatwise in nested relation to form a third leg portion and yoke portions disposed at right angles to the third leg portion, the yoke portions of said U-shaped core member being disposed at substantially a right angle with respect to the plane of said closed loop member with the ends of alternate layers of laminations in the yoke portions of said U-shaped core member being disposed in the recesses of the yoke portions of said closed loop member.

4. A there-phase magnetic core comprising a substantially rectangular closed loop member including a plurality of layers of laminations formed from magnetic strip material having a preferred direction of orientation substantially parallel to longitudinal edges of the strip material and assembled flatwise in nested relation two parallel sides of said rectangular loop member forming first and second leg portions and the other parallel sides forming first and second yoke portions connecting said first and second leg portions alternate layers of lamiantions of said loop member each comprising first and second generally U-shaped laminations disposed at the first and second yoke portions of said core respectively with the ends of each of said first and second U-shaped laminations extending into said first and second leg portions and meeting to form butt joints the layers of laminations intervening said layers of U-shaped laminations each comprising four generally L-shaped laminations disposed with certain ends of two of the L-shaped laminations butting against each other in said first leg portion and certain ends of the remaining two L-shaped laminations butting against each other in said second leg portion, the remaining ends of said L-shaped laminations extending into said first and second yoke portions and spaced from each other to form recesses therein, and a generally U-shaped core member including a plurality of layers of generally L-shaped laminations formed from magnetic strip material having at least two preferred directions of magnetic orientation and assembled flatwise in nested relation to form a third leg portion and yoke portions disposed at right angles to the third leg portion, the yoke portions

of said U-shaped core member being disposed at substantially a right angle with respect to the plane of said closed loop member with the ends of alternate layers of laminations in the yoke portions of said U-shaped core member being disposed in the recesses of the yoke portions of said closed loop member, the meeting ends of the U-shaped and L-shaped laminations in the leg portions of said core in successive layers of laminations being displaced from each other by a predetermined distance to form a series of stepped-lap joints in each of said leg portions.

5. A three-phase magnetic core comprising a substantially rectangular core loop including a plurality of layers of laminations formed from magnetic strip material and assembled in nested relationship to form first and second substantially parallel leg portions and yoke portions connecting said leg portions at opposite ends of said core loop, the layers of laminations of each of said yoke portions each including a substantially rectangular recess, the recesses in successive layers of laminations being formed in a stepped recurring pattern, and a generally U-shaped core member including a plurality of layers of laminations formed from magnetic strip material having at least two preferred directions of magnetic orientation and assembled in nested relationship to form a substantially straight third leg portion and yoke portions disposed substantially perpendicular to the third leg portion, the yoke portions of said U-shaped member being disposed at substantially a right angle to the plane of said core loop with the ends of the laminations of the yoke portions of said U-shaped member being disposed in the recesses of the layers of laminations of the yoke portions of said core loop to form a series of stepped-lap joints with each of the yoke portions of said core loop.

6. A three-phase magnetic core comprising a substantially rectangular core loop including a plurality of layers of discrete laminations formed from magnetic strip material and assembled in nested relationship to form first and second substantially parallel leg portions and first and second yoke portions connecting said first and second leg portions at opposite ends of said core loop, the layers of laminations of each of said yoke portions each including a substantially rectangular recess, the recesses in successive layers of laminations being formed in a stepped recurring pattern, and a generally U-shaped core member including a plurality of layers of laminations formed from magnetic strip material having at least two preferred directions of magnetic orientation and assembled in nested relationship to form a substantially straight third leg portion and yoke portions disposed substantially perpendicular to the third leg portion, the yoke portions of said U-shaped member being disposed at substantially a right angle to the plane of said core loop with the ends of the laminations of the yoke portions of said U-shaped member being disposed in the recesses of the layers of laminations of the yoke portions of said core loop to form a series of stepped-lap joints with each of the yoke portions of said core loop, each layer of laminations of each of said leg portions being cut to provide ends that are substantially at right angles to longitudinal edges of the laminations and assembled with the cut ends of the laminations of each layer being substantially aligned and displaced from those in the adjacent layers to overlap the cut ends of the laminations in the adjacent layers and form a series of stepped-lap joints.

7. A three-phase magnetic core comprising three generally U-shaped core members each including a plurality of layers of lamiantions formed from magnetic strip material having a preferred direction of orientation substantially parallel to longitudinal edges of the strip material, the laminations of each of said core members being assembled flatwise in nested relation to form a substantially straight leg portion and yoke portions disposed at substantially right angles to said leg portion, the ends of the layers of laminations of the yoke portions at both ends of said core members being cut substantially perpendicular to longitudinal edges of the laminations, the cut ends of the laminations being displaced from the cut ends of the laminations in the adjacent layers by a predetermined distance in stepped relation, and first and second pluralities of layers of magnetic inserts formed from magnetic sheet material having at least two preferred directions of orientation and stacked with at least three sides of said inserts in successive layers being disposed in stepped relation, the respective yoke portions of each of said core members being assembled on the three sides of said first and second pluralities of layers of inserts with the laminations of said yoke portions substantially aligned with the adjacent inserts to form a series of stepped-lap joints between each of said yoke portions and each of said pluralities of layers of inserts, the yoke portions of said core members being disposed at predetermined angles with respect to each other.

8. A three-phase magnetic core comprising three generally U-shaped core members each including a plurality of layers of laminations formed from magnetic strip material having a preferred direction of orientation substantially parallel to its longitudinal dimension, the laminations of each of said core members being assembled flatwise in nested relation to form a substantially straight leg portion and yoke portions disposed substantially at right angles to said leg portion, the ends of the layers of laminations being cut substantially perpendicular to longitudinal edges of the laminations, the cut ends of each layer of laminations being displaced from the cut ends of the adjacent layers of laminations by a predetermined distance in stepped relation, and a plurality of substantially rectangular inserts at each end of said core formed from magnetic sheet material having a first preferred direction of orientation substantially parallel to its longitudinal dimension and a second preferred direction of orientation transverse thereto, the plurality of inserts at each end of said core being stacked with at least three corresponding sides of successive inserts arranged in recurring stepped relation, two of said core members being assembled on two opposite sides of said three sides of said plurality of inserts at each end of said core with the layers of laminations of each yoke portion of each of said core members substantially aligned with each plurality of inserts to form a series of stepped-lap joints with said inserts at each end of said core, the third of said core members being assembled on the third of said three sides of said inserts at substantially a right angle with respect to the plane of said two core members with the laminations of said core member substantially aligned with the inserts at each end of said core to form recurring series of stepped-lap joints.

9. A three-phase magnetic core comprising three generally U-shaped core members each including a plurality of layers of laminations formed from magnetic strip material having a preferred direction of orientation substantially parallel to its longitudinal dimension, the laminations of each of said core members being assembled flatwise in nested relation to form a substantially straight leg portion and yoke portions disposed substantially at right angles to said leg portion, the ends of the layers of laminations being cut substantially perpendicular to longitudinal edges of the laminations thereof, the cut ends of each layer of laminations being displaced from the cut ends of the adjacent layers of laminations by a predetermined distance in stepped relation, and a plurality of triangular and hexagonal inserts at each end of said core formed from magnetic strip material having at least two preferred directions of orientation, the plurality of inserts at each end of said core being stacked with at least three corresponding sides of successive inserts being parallel and offset from each other in recurring stepped relation, each of said core members being assembled with the layers of laminations of each of the yoke portions in substantial alignment with the corresponding sides of the inserts at

each end of said core to form recurring series of stepped-lap joints, the yoke portions of said core members being displaced from each other by substantially equal angles around a central axis of said core.

10. A three-phase magnetic core comprising three generally U-shaped core members each including a plurality of layers of laminations formed from magnetic strip material having a preferred direction of orientation substantially parallel to its longitudinal dimension, the laminations of each of said core members being assembled flatwise in nested relation to form a substantially straight leg portion and yoke portions disposed substantially at right angles to said leg portion, the ends of the layers of laminations being cut substantially perpendicular to the longitudinal edges of the laminations, the cut ends of each layer of laminations being displaced from the cut ends of the adjacent layers of laminations by a predetermined distance in stepped relation, and a plurality of substantially rectangular inserts at each end of said core formed from magnetic sheet material having a first preferred direction of orientation substantially parallel to its longitudinal dimension and a second preferred direction of orientation transverse thereto, the plurality of inserts at each end of said core being stacked with at least three corresponding sides of successive inserts arranged in recurring stepped relation, two of said core members being assembled on two opposite sides of said three sides of said plurality of inserts at each end of said core with the layers of laminations of each yoke portion of each of said core members substantially aligned with each plurality of inserts to form a series of stepped-lap joints with said inserts at each end of said core, the lengths of the sides of the inserts which are substantially parallel to the plane of said two core members being substantially a predetermined value, the third of said core members being assembled on the third of said three sides of said inserts at substantially a right angle with respect to the plane of said two core members with the laminations of said core member substantially aligned with the inserts at each end of said core to form recurring series of stepped-lap joints.

11. A three-phase magnetic core comprising three generally U-shaped core members each including a plurality of layers of laminations formed from magnetic strip material having a preferred direction of orientation substantially parallel to its longitudinal dimension, the laminations of each of said core members being assembled flatwise in nested relation to form a substantially straight leg portion and yoke portions disposed substantially at right angles to said leg portion, the ends of the layers of laminations being cut substantially prependicular to longitudinal edges of the laminations thereof, the cut ends of each layer of laminations being displaced from the cut ends of the adjacent layers of laminations by a predetermined distance in stepped relation, and a plurality of substantially rectangular inserts at each end of said core formed from magnetic sheet material having a first preferred direction of orientation substantially parallel to its longitudinal dimension and a second preferred direction of orientation transverse thereto, the plurality of inserts at each end of said core being stacked with at least three corresponding sides of successive inserts arranged in recurring stepped relation, two of said core members being assembled on two opposite sides of said three sides of said plurality of inserts at each end of said core with the layers of laminations of each yoke portion of each said core members substantially aligned with each plurality of inserts to form a series of stepped-lap joints with said inserts at each end of said core, the respective lengths of the sides of the inserts which are substantially parallel to the plane of said two core members and the sides which are transverse thereto both varying in steps in successive inserts; the third of said core members being assembled on the third of said three sides of said inserts at substantially a right angle with respect to the plane of said two core members with the laminations of said core member substantially aligned with the inserts at each end of said core to form recurring series of stepped-lap joints.

12. A three-phase magnetic core comprising three generally U-shaped core members each including a plurality of layers of generally L-shaped laminations formed from magnetic strip material having at least one preferred direction of orientation substantially parallel to its longitudinal dimension and assembled flatwise in nested relation to form a substantially straight leg portion and yoke portions disposed at substantially right angles to said leg portion, said U-shaped core members being assembled with the yoke portions of said core members meeting in a common joint at each end of said core and with one core member being disposed substantially perpendicular to the plane formed by the other two core members, the ends of the layers of laminations of the yoke portions of said core members being progressively interleaved in sequence at each end of said core to form a series of overlapping joints, the magnetic strip material from which the laminations of said one core member are formed also having a second preferred direction of orientation transverse to the longitudinal dimension of said material.

13. A three-phase magnetic core comprising three generally U-shaped core members each including a plurality of layers of generally L-shaped laminations formed from magnetic strip material having at least one preferred direction of orientation substantially parallel to its longitudinal dimension and assembled flatwise in nested relation to form a substantially straight leg portion and yoke portions disposed at substantially right angles to said leg portions, said U-shaped core members being assembled with the yoke portions of said core members meeting in a common joint at each end of said core and with one core member being disposed substantially prependicular to the plane formed by the other two core members, the ends of the layers of laminations of the yoke portions of said core members being progressively interleaved in sequence at each end of said core to form a series of overlapping joints, the magnetic strip material from which the laminations of said one core member are formed also having a second preferred direction of orientation transverse to the longitudinal dimension of said material, the ends of the layers of laminations of each of said leg portions being cut substantially perpendicular to the edges thereof and assembled with the cut ends of each layer being substantially aligned and displaced from those in the adjacent layers to overlap the cut ends of the laminations in the adjacent layers and form a series of stepped-lap joints.

References Cited by the Examiner

UNITED STATES PATENTS

2,456,461	12/48	Dunn	336—217 X
2,486,220	10/49	Somerville	336—217
2,958,931	11/60	Hurt	336—217 X
2,964,836	12/60	Smith	336—217 X

FOREIGN PATENTS

490,505	2/53	Canada.

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