Jan. 4, 1955 T. D. GORDY 2,698,924

THREE-PHASE SPLIT MAGNETIC CORE

Filed Feb. 29, 1952

Fig. 1.

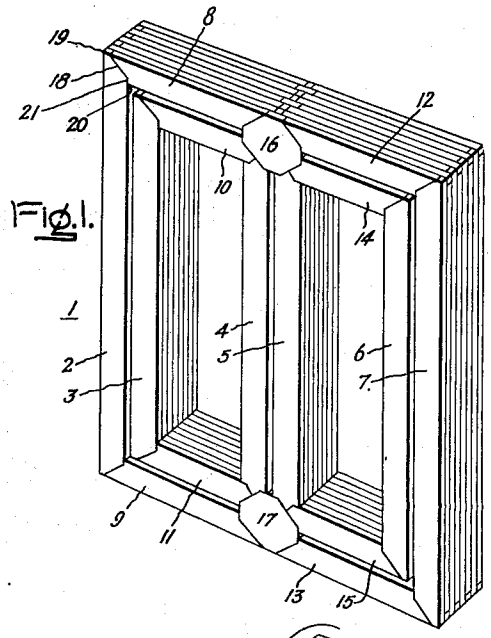


Fig. 2.

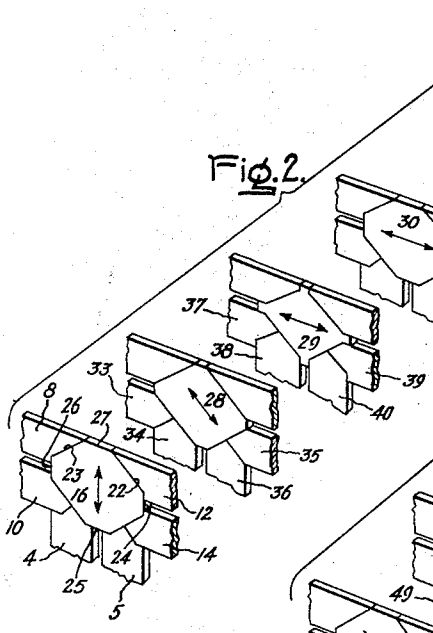
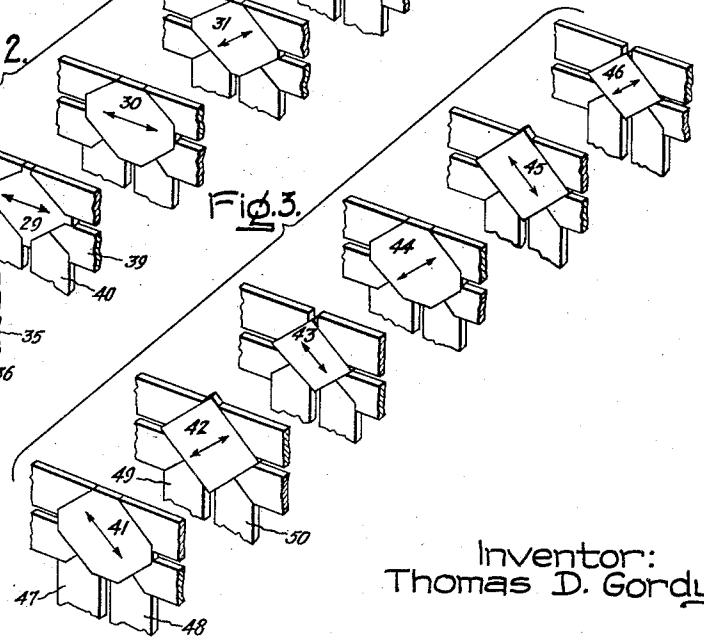


Fig. 3.



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United States Patent Office 2,698,924 Patented Jan. 4, 1955

2,698,924

THREE-PHASE SPLIT MAGNETIC CORE

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Application February 29, 1952, Serial No. 274,242

2 Claims. (Cl. 336—215)

This invention relates to magnetic cores for stationary electrical induction apparatus and more particularly to laminated three-phase magnetic cores of the split or divided type.

The laminations for the magnetic cores of stationary electrical induction apparatus very often are punched or cut from sheets of magnetic material which are produced by rolling from bars or billets of suitable ferromagnetic material. The rolling process forms a grain structure in the sheets which normally extends in the direction in which the sheets have been rolled. It has been found that the path which offers the least reluctance to magnetic lines of flux through these rolled sheets and the path which has least core loss is parallel to the direction of the grain. Thus, to present a magnetic core having the lowest reluctance and core loss for a given size it is advantageous to assemble the core sections in such a manner as to allow the magnetic flux to follow continuously the line of the grain of the ferro-magnetic core laminations.

In the normal lapped core construction, it can be seen that the magnetic flux must cut crosswise of the most favorable direction at the ends of the laminations in traversing from one core leg to the next. Due to the crosswise flow of flux at the corners of the core relatively high losses occur at these points. One way of overcoming the difficulties just referred to is to have mitered joints at the corners of the core between mating laminations of the yoke and leg members of the core. With such a miter joint arrangement at the corners of the core, the magnetic lines of flux run substantially parallel in all sections of the core to the grain orientation of the laminations. Thus, by the use of miter joints core losses and excitation may be decreased.

A still further reduction in core losses can be obtained using laminations of the split or divided type, such as are shown in my Patent 2,467,823, issued April 19, 1949, and assigned to the same assignee as the present application. In accordance with the split or divided lamination construction shown in the patent just mentioned, each layer of each of the leg and yoke members is divided longitudinally into two or more parallel strips lying in the same plane. One advantage of such a construction is that the cost of constructing a large core is reduced since the leg and yoke portions can be made from relatively narrow standard ferro-magnetic strip widths. Thus, the necessity of using a highly expensive oversized width stock on large size cores is unnecessary. Also, a further advantage is the fact that an improved flux path characteristic is obtained with the split or divided lamination construction since the magnetic flux tends to remain in the individual laminar strips, thus providing better distribution of the magnetic flux throughout the length of the strips, and at the corners of the core. A further advantage of divided laminations is the consequent reduction of eddy current losses due to the narrower dimensions of each laminar section.

Magnetic cores of the split or divided type are generally of large size and it is often desirable to provide special cooling means for the magnetic core. One way of providing such a cooling effect is to space the longitudinally split yoke and leg sections apart from each other in such manner as to provide a cooling duct between the respective leg and yoke sections.

In a three-phase magnetic core of the split type, means must be provided for obtaining a common junction for the multiple magnetic flux paths set up by the three-phase

windings in order to provide a full flux transfer between any two paths. It is desirable that such a junction take advantage as much as possible of the oriented characteristic of the magnetic material forming the core, taking into consideration the fact that the direction of the magnetic flux passing through the common junction changes from one instant to another due to the phase displacement of the magnetic fluxes in the respective winding legs.

Accordingly, it is an object of my invention to provide a new type of magnetic interconnection between the three winding legs of a three-phase magnetic core of the split type.

It is a further object of my invention to provide a new type of magnetic interconnection between the three winding legs of a three-phase magnetic core formed of oriented magnetic material which utilizes to best advantage within practical limits the oriented characteristics of the magnetic material of which the core is formed.

It is a still further object of my invention to provide a new and improved construction for a split or divided type magnetic core which provides ducts between the respective split portions of the core for the passage of a suitable cooling fluid.

In accordance with these objectives, my invention provides a T-joint interconnection arrangement for the flux paths of a three-phase magnetic core of the split type in accordance with which insert members of oriented magnetic material are provided at the common junction of the flux paths for the three phases, with the grain orientation of insert members for adjacent layers being shifted in order to provide equally favorable paths for the various instantaneous magnetic fluxes passing through the junction.

The features of this invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and use, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 is an elevation view of a three-phase magnetic core of the split type constructed in accordance with my invention; Fig. 2 is a view showing the insert arrangement at the T-joint for a group of successive layers of the magnetic core of Fig. 1 by means of which the magnetic paths of the three phases are provided with a common junction; while Fig. 3 is a view showing an embodiment of my invention in which slightly modified insert members are used as compared to the construction of Fig. 1.

Referring now to Fig. 1, there is shown therein a three-phase magnetic core of the split type which is indicated generally at **1**. The outermost layer of the left-hand core leg, with respect to the view shown in the drawing, is split into two longitudinally extending lamination strips **2** and **3**. The outermost layer of the center core leg is split into two longitudinally extending strips **4** and **5** and the outermost layer of the right-hand core leg is split into two longitudinally extending strips **6** and **7**. The laminar strips for each layer of any given core leg member or yoke member are spaced apart so that the separation between the respective split laminations for the plurality of layers forms a duct extending transverse to the plane of the laminations. This separation between the respective laminar strips lying in the respective leg and yoke members forms an inner and an outer core section, with the inner and outer core sections being joined together at the center leg by oriented insert members in accordance with my invention.

In each layer of the core the respective split laminations comprising each leg member are joined to similar split laminations in the yoke portion of the core. Thus, in the outermost layer of the core of Fig. 1 laminar strip **2** of the left-hand core leg is joined by mitered joints at its upper and lower ends, respectively, to yoke strip members **8** and **9** which lie in the outer core section; while strip member **3** of the left-hand core leg is joined by mitered joints at its upper and lower ends, respectively, to yoke strips **10** and **11** which lie in the inner core section. Similarly, in the right-hand core leg, with respect to the view shown in the drawing, the outer strip member **7** is

joined by mitered joints at its upper and lower ends, respectively, to strip members **12** and **13** lying in the outer core section; while strip member **6** is joined by mitered joints at its upper and lower ends, respectively, to yoke strip members **14** and **15** which lie in the inner core section. Center leg strip **4** is joined at its upper and lower ends, respectively, to yoke strips **10** and **11**, while center leg strip **5** is joined at its upper and lower ends, respectively, to yoke strips **14** and **15**.

In order to provide a magnetic connection between the outer core and the inner core, and to provide a magnetic junction between the flux paths of the three core legs, polygonal rectangular-like insert members **16** and **17** are positioned at the upper and lower ends of the core, respectively. As will be described in more detail in connection with Fig. 2, polygonal insert member **16** is jointed to yoke strips **8** and **12** of the outer core section, to yoke strips **10** and **14** of the inner core section, and to strip members **4** and **5** of the center core leg. Similarly, insert member **17** is jointed to yoke strips **9** and **13** of the outer core section, to yoke strips **11** and **15** of the inner core section, and to the lower ends of strips **4** and **5** of the center core leg.

Each leg strip lying in the outer core legs is preferably joined to its mating yoke strip by a miter joint, as shown in the drawing. These miter joints are preferably of the overlap type such as are shown in Fig. 1 in which each miter joint is offset from a diagonal running from the outer corner formed by the outer edges of a given pair of mating leg and yoke strips to the inner corner formed by the inner edges of the same mating leg and yoke strips. Thus, referring to Fig. 1 there is shown a miter joint **18** between laminar strip **2** of the left-hand leg member and the mating laminar strip **8** of the yoke member. Miter joint **18** is offset to the right, with respect to the view shown in the drawing, from the diagonal which runs between outside corner **19** and inside corner **20**. Due to the offset characteristic of the joint, if the yoke strip **8** were cut at the same continuous miter angle from its outer to its inner edge, a portion of yoke strip **8** adjacent the inner corner **20** would be cut away. In order to avoid this, the mitered edge of yoke strip **8** is discontinued when it reaches a point in alignment with the inner edge of leg strip **2**, and yoke strip **8** is provided with an edge portion **21** which is parallel to the inner edge of the leg strip **2**. The mitered joints between each pair of mating leg and yoke strips in the left and right core legs are preferably formed in the same manner.

The direction of offset of the miter joints for adjacent layers are reversed with respect to one another to provide an overlapping between the joints for adjacent layers. Thus, the miter joint for the layer immediately underneath the outermost layer just described is offset to the left, with respect to the view shown in the drawing, of the diagonal line running from corner **19** to corner **20**.

In accordance with my invention I have magnetically interconnected the inner and outer cores together in a T-joint at the center leg of the core and at the same time have provided a junction for the magnetic fluxes of all three core legs by means of polygonal insert members of oriented magnetic material which are positioned in such manner that the insert members lying in successive layers have their orientation shifted so as to provide, within practical limits, equally favorable paths for the various directions of flux travel. Furthermore, the insert members are positioned angularly with respect to the longitudinal and transverse axes of the core in such manner as to provide a mitered joint effect between the edges of the insert members and the laminations with which the insert members mate.

Referring now to Fig. 2, there is shown the insert member **16** which is also shown in the uppermost layer of the core of Fig. 1.

It will be noted that the axis of the insert member **16** is arranged at an angle of substantially 45 degrees with respect to the longitudinal axis of the center leg in such manner that the side edges **22** and **23** of the insert member form a miter joint with the edges of yoke strips **12** and **8**, respectively. The edges of insert member **16** form miter joints with yoke strips **10** and **14**. The corners of the insert member **16** are trimmed in such manner as to be in alignment with the respective edges of the yoke and leg strips. That is, for example, the right-hand corner edge **24** is in alignment with the right-hand edge of center leg strip **5**, the bottom edge **25** of insert member **16** is in alignment with the bottom edges of yoke strips **10** and **14**, the left-hand edge **26** of the insert member is in alignment with the left-hand edge of leg strip **4**, and the upper edge **27** of the insert member is in alignment with the upper edges of yoke strips **8** and **12**. In other words, the overall dimensions of the insert member **16** conform to the total widths of the two strip members of the center leg and also to the total width of the two strips **8** and **10** or **12** and **14** of the yoke.

The successive adjacent layers of the core are respectively provided with insert members **28**, **29**, **30**, **31** and **32** in the particular embodiment illustrated in the drawing, in which a six-step sequence is used.

In order to provide equally favorable flux path characteristics for substantially all of the magnetic flux which passes through the insert members at each instant and taking into consideration the changing directions of magnetic flux travel due to the time displacement of the three-phase windings on the core, I use successive insert members which are oriented in different directions. The directions of grain orientation of the respective insert members are indicated by the arrow member positioned on each of the inserts. Thus, the arrow for insert **16** indicates that the grain orientation of this insert is parallel to the grain orientation of the center leg member and substantially perpendicular to the grain direction of the yoke strips **12** and **14**. The arrow shown on insert member **28** indicates that the grain orientation of this insert member is rotated substantially 45° in a counterclockwise direction from the direction of the grain of insert member **16**. The arrow for insert member **29** indicates that the grain of this insert member is oriented in a direction which is substantially perpendicular to the direction of orientation of the grain of insert member **16** and substantially parallel to the grain direction of the yoke strips **37** and **39**. The arrow shown on insert member **30** indicates that its grain is oriented in the same direction as that of insert member **29** and is positioned substantially perpendicularly to the orientation of insert member **16**. The direction arrow on insert **31** indicates that its grain has been rotated substantially 45° in a clockwise direction with respect to the orientation of the grain of insert member **16**; while the direction arrow on insert **32** indicates that its grain orientation is the same as that of insert member **16**.

In order to obtain an offset relation between the joints of the yoke and leg strip members which meet at the center core leg, I shift the position of the joints between corresponding yoke and leg strips for adjacent layers as will now be described. It will be noted that in the laminar layer containing insert member **16**, leg strips **4** and **5** are each notched to receive yoke strips **10** and **14**, respectively, and the miter joint between yoke strip **10** and leg strip **4** is positioned inwardly of the left edge of yoke strip **4**; similarly, the miter joint between yoke strip **14** and leg strip **5** is positioned inwardly of the right-hand edge of leg strip **5**. In the layer containing insert member **28**, the joint between yoke strip **33** and leg strip **34** and between yoke strip **35** and leg strip **36** each respectively extend directly from the corner formed by the edges of the respective yoke and leg strips. In the laminar layer containing insert member **29**, the respective yoke strips **37** and **39** are notched in order to receive the ends of leg strips **38** and **40**, respectively, in such manner as to offset the joints for this layer with respect to the corresponding joints for the layers containing insert members **16** and **28**, respectively. The joints for the layers containing insert members **30**, **31** and **32** are respectively arranged in the same manner as the joints for the layers containing insert members **16**, **28** and **29** just described.

In order to obtain an overlapping or offsetting of the joints between the insert members for adjacent layers, the widths of the respective insert members in a direction perpendicular to their respective longitudinal axes are staggered in a manner which will now be described. It will be noted that insert members **16**, **28**, and **29** become progressively narrower, insert member **16** being wider than inserts **28** and **29**, and insert **28** being wider than insert **29**. This width sequence is repeated with inserts **30**, **31** and **32**.

In the lamination layer containing insert member **16**, each of the respective yoke and leg strips which are joined to insert member **16** have a mitered edge contact with the insert member along most of the contact edge, except for a short portion of the edge of the insert member which is perpendicular to the longitudinal edge of the respective

leg or yoke strip. In the layer containing insert member **28** the respective yoke and leg strips are mitered along the entire length of all edges where they abut the insert member **28**. The insert member **29**, which is narrower than either insert member **16** or **28**, is joined to each of the respective leg and yoke strips coming together at the insert by mitered edges displaced inwardly of the outer corners of the insert member. The outer corners of insert member **29** project outwardly like ears from the main body of the insert member. Insert members **30, 31** and **32** are similar, respectively, to insert members **16, 28** and **29**.

There is shown in Fig. 3 a modified embodiment of my invention in accordance with which a slightly modified type of insert is used as compared to the insert members used in the construction of Fig. 2. In Fig. 3, I have shown a plurality of laminar layers having insert members **41, 42, 43, 44, 45** and **46**, respectively. Each of these insert members is positioned in such manner that its longitudinal axes are at an acute angle with respect to the longitudinal axis of the yoke and leg strips which the respective insert members join together. Thus, a mitered joint effect is obtained between the respective abutting edges of the various insert members and the yoke and leg strips with which the insert members are in abutting relation. The insert members shown in Fig. 3 are of oriented magnetic material and the direction of orientation of the grain of insert members for adjacent layers may be disposed in such manner as to at least partially conform to the changing direction of magnetic flux travel through the junction formed by the respective insert members. In the embodiment shown in Fig. 3 I have used two different directions of grain orientation. Thus, the grain orientation of insert **41** is shifted 45° in a counterclockwise direction from the direction of grain orientation of the leg strips **47** and **48**. The direction of orientation of the grain of insert member **42** is substantially perpendicular to the orientation of the grain of insert member **41** and is rotated substantially 45° in clockwise direction from the direction of orientation of the grain of leg members **49** and **50**. Adjacent insert members in the embodiment of Fig. 3 have their respective grain orientations arranged mutually perpendicularly to each other and alternate insert members have the same grain orientation. Thus inserts **41, 43** and **45** all are aligned in the same direction; and the grain of insert members **42, 44** and **46** are all aligned in the same direction.

The insert members shown in Fig. 3 are in general similar to those shown in Fig. 2 in that the widths of the successive insert members are progressively staggered. Thus, insert members **41, 42** and **43** become progressively narrower in width, in the manner previously described for insert members **16, 28** and **29** of Fig. 2. The principal difference in the physical shape of the insert members of Fig. 3 as compared to those of Fig. 2 is that insert members **42** and **43** do not have trimmed corners or ears. Thus, the corners of insert member **42** project outwardly beyond the edges of the respective yoke and leg strips, and the corners are not cut off as is done in the case of insert member **28** of Fig. 2. Similarly, insert member **43** has its corners displaced inwardly with respect to the outer edges of the yoke and leg strips which it joins, and is not provided with ear extensions similar to those used in connection with insert member **29** of the embodiment of Fig. 2.

From the foregoing description, it can be seen that I have provided a new and improved arrangement for interconnecting the yoke and leg strips of the inner and outer core sections of a three-phase split type magnetic core. I have provided a junction for a multiple magnetic flux path set up by the three phase windings which provides a full flux transfer between any two magnetic paths utiiizing the oriented characteristics of the magnetic material of which the core is formed.

While there have been shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that various changes and modifications can be made therein without departing from the invention and, therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

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

1. In a three-phase magnetic core formed of a plurality of layers of flat-stacked strips of magnetic material having its grain oriented substantially parallel to the lengthwise direction of said strips, said core comprising a plurality of longitudinally divided winding leg members joined by longitudinally divided yoke members to form an inner and an outer core section, a T-joint formed at the junction between two aligned yoke members and a winding leg member which is positioned substantially perpendicularly to said aligned yoke members, each of said yoke and leg members at said T-joint in a given layer of said core comprising two laminations extending parallel to each other but separated for substantially their entire length by a gap, said T-joint comprising in a given layer an insert member of grain oriented magnetic material having four side edges, said insert member being positioned with said four side edges obliquely arranged with respect to the respective longitudinal axes of said yoke and leg members at said T-joint, the ends of all of said laminations of said yoke and leg members at said T-joint abutting said insert member at the side edges thereof, at least a portion of the inner core section yoke members and leg members at said T-joint also making direct mitered butt contact with each other to the exclusion of said insert member, the insert members for adjacent layers of said core having their respective grain orientations disposed in such manner as to present favorable grain orientations for at least two different directions of magnetic flux travel through said insert members.

2. In a three-phase magnetic core formed of a plurality of layers of flat stacked strips of magnetic material having its grain oriented substantially parallel to the lengthwise dimension of said strips, said core comprising a plurality of longitudinally divided winding leg members joined by longitudinally divided yoke members to form an inner and an outer core section, a T-joint formed at the junction between two aligned yoke members and a winding leg member which is positioned substantially perpendicularly to said aligned yoke members, each of said yoke and leg members at said T-joint in a given layer of said core comprising two laminations extending parallel to each other but separated for substantially their entire length by a gap, said T-joint comprising in a given layer an insert member of grain oriented magnetic material, said insert member being rectangular-like with its side edges obliquely arranged with respect to the respective longitudinal axes of said yoke and leg members at said T-joint, the end edges of all of said laminations of said yoke and leg members at said T-joint abutting said insert member at the side edges thereof, at least a portion of the respective abutting edges between said respective leg and yoke laminations and said insert member being mitered, at least a portion of the inner core section yoke members and leg members at said T-joint also making direct mitered butt contact with each other to the exclusion of said insert member, the insert members for adjacent layers of said core having their respective grain orientations shifted with respect to each other to present favorable grain orientations for at least two different directions of magnetic flux travel through said insert members, and the insert members for adjacent layers of said core having different dimensions whereby said mitered edges of adjacent layers of said core overlap each other.

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