Aug. 21, 1951 H. L. GARBARINO 2,565,303

MAGNETIC CORE JOINT CONSTRUCTION FOR NOISE REDUCTION

Filed July 14, 1950

Fig. 1.

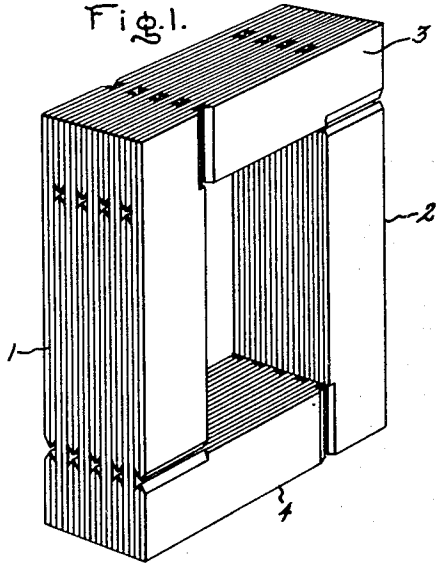


Fig. 2.

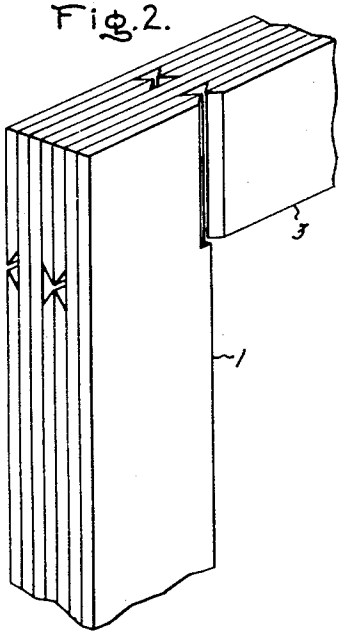


Fig. 3.

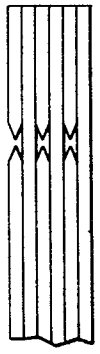


Fig. 4.

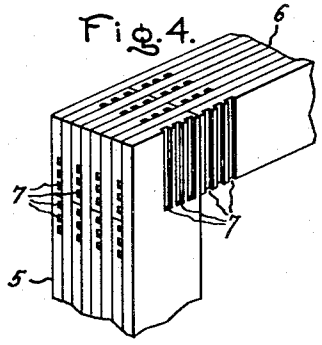
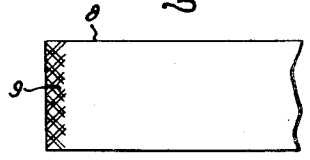


Fig. 5.



Inventor:
Harold L. Garbarino,
by Ernest C. Britton
His Attorney.

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MAGNETIC CORE JOINT CONSTRUCTION FOR NOISE REDUCTION

Harold L. Garbarino, Pittsfield, Mass., assignor to General Electric Company, a corporation of New York

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11 Claims. (Cl. 175—356)

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This invention relates to magnetic cores for stationary electrical induction apparatus, and more particularly to an improved joint construction for such magnetic cores.

In the construction of magnetic cores for stationary electrical induction apparatus it is often necessary that the laminations of magnetic material which constitute the magnetic core be jointed at various places throughout the magnetic circuit. It is general practice to utilize a lap joint construction in accordance with which the joints for successive laminar layers or groups of laminar layers are offset from one another in order that the composite joint structure in any particular region of the core have improved mechanical and magnetic characteristics. If all of the joints for successive layers in the same region of the core were along the same cross-sectional line, a mechanically weak joint would result. Furthermore, such a joint would ordinarily have an excessively high magnetic reluctance which would adversely affect the magnetic and electrical characteristics of the core.

One difficulty which has been encountered with present joint constructions for magnetic cores is that a considerable portion of the noise level of such magnetic cores is due to vibration of the magnetic laminations in the joint regions of the core. This vibration of the laminations in joint regions of the core may be explained in terms of the magnetic flux paths in proximity to the joints. Where two laminations, or the adjacent ends of one lamination, in the same plane come together, there is a small gap called a butt gap or butt joint which is present due to the difficulty of fitting the laminations so closely together that this gap is completely eliminated. Such a gap provides a high reluctance path for the magnetic flux, so that most of the flux approaching the joint crosses to the adjacent layers of magnetic laminations in a direction approximately perpendicular to the plane of the laminations. Therefore, it can be seen that the density of magnetic flux in the layers of magnetic material adjacent to one of these butt gaps is considerably greater than the average density in a cross section of the core having no joints.

An analysis which I have made shows that the magnetic flux crossing from one laminar layer to another to by-pass a butt gap has its greatest density close to the butt gap. In other words, most of the flux in any given laminar layer waits until it reaches the very edge of the butt gap before it crosses in a perpendicular plane to the adjacent laminar layers, and very little of the

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flux passes over to the adjacent laminar layers before reaching the edge of the butt gap. This flux passage at the edge of the butt gaps causes mechanical forces which can be shown to be proportional to the square of flux density. It is this concentration of flux at the edge of the butt gaps which is an important factor in causing the laminar vibrations which raise the noise level of the magnetic core.

Accordingly, it is an object of my invention to provide a joint construction for magnetic cores which will reduce the noise level due to vibration in the joint region of the core.

It is a further object of my invention to provide a new and improved joint construction for laminated magnetic cores in accordance with which magnetic flux density in the region of the butt gaps will be reduced.

It is a further object of my invention to provide a high reluctance region in the immediate vicinity of butt gaps between magnetic laminations in order that most of the magnetic flux approaching a gap in any given laminar layer will cross to adjacent laminar layers before reaching the immediate vicinity of the butt gap, and thereby reduce the vibratory noise level of the magnetic core.

In accordance with these objectives, my invention provides a joint construction having an increased magnetic reluctance in the immediate vicinity of the butt gaps lying in the joint region so that most of the magnetic flux in the region of such butt gaps will be caused to pass over to adjacent laminar layers before reaching the immediate vicinity of the butt gaps. By decreasing the concentration of flux crossing to adjacent laminar layers in the immediate vicinity of butt gaps, I reduce the force in a direction perpendicular to the plane of the laminations. By thus providing a construction which redistributes the flux in the joint region, I can obtain substantial reduction in the noise level of the magnetic core due to vibrations of the magnetic laminations.

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 represents a complete magnetic core in which I utilize a beveled edge construction to obtain increased reluctance at the edge of butt gaps; Fig. 2 represents an en-

larged view of one of the joint regions of the core Fig. 1; Fig. 3 represents a modified beveled edge construction; while Figs. 4 and 5 show modified joint constructions in which mating lamination edges are scored or grooved to provide increased reluctance at the edge of butt gaps.

Referring now to Fig. 1, there is shown a magnetic core of generally rectangular shape constructed of stacked laminations of magnetic material. This core is composed of leg members 1 and 2 at opposite sides of the core, the corresponding ends of the two legs members being joined together by yoke members 3 and 4. The laminations comprising legs 1 and 2 and yoke members 3 and 4 are assembled in accordance with the well-known butt and lap method of assembly. Thus, for example, the laminations comprising core leg 1 extend alternately to the upper and lower edge of the core with respect to the view shown in Fig. 1, while the corresponding laminations for yoke members 3 and 4 extend alternately to the right and left edges of the core, with respect to the view shown in the drawing.

In the particular embodiment shown in Figs. 1 and 2, I have stacked laminations two at a time, so that the first and second layers have the same arrangement of laminations, the third and fourth layers have a similar laminar arrangement, etc. However, I may stack laminations one at a time, three at a time, or any other desired number at one time. Thus, considering the two top laminated layers shown in the view of Fig. 1, the lamination of leg 1 for each of the first two layers extends to the upper edge of the core; the lamination of yoke member 3 for each of the first two layers butts against the right side edge of the lamination of leg 1, with the other end of each of these same yoke laminations extending flush with the right-hand edge of the core. On each of the succeeding two layers, the lamination for leg 1 extends to the bottom edge of the core, and the corresponding lamination for upper yoke 3 extends to the left-hand edge of the core. It can be seen that this construction provides an overlapping relation for the successive laminated layers of the core.

In accordance with my invention, wherever a joint occurs between two laminated members in the same layer, I have provided a high reluctance path immediately adjacent the joint butt gap so that most of the magnetic flux will be caused to cross over to adjacent laminated layers before reaching the edge of the joint. By this construction, I have reduced to a large extent the forces and vibration at the ends of the laminar members caused by the excessive flux density present at the actual edge of the laminar joints.

In the embodiment of my invention shown in Figs. 1, 2 and 3, I have achieved this high reluctance at the edge of the joints by beveling the laminated edges which meet to form the joint. Thus, it will be noted in Figs. 1 and 2 that the side of the outermost lamination in leg 1 which meets the lamination of yoke member 3 is beveled along the surface where the butt joint between these two members occurs. Similarly, the edge of the lamination of yoke member 3 is beveled along the edge which abuts against the lamination of leg member 1. The upper edge of the lamination of leg 2 is beveled where it butts against the lower edge of the lamination of yoke member 3 which, in turn, is also beveled along the joint edge. Similarly, wherever laminations of leg and yoke members are in abutting relation, I have beveled the abutting edges as shown in Figs. 1, 2 and 3.

In beveling the edges of the laminations at the joint surface, I may bevel each lamination on only one side and then lay two such laminations together so that the beveled edges of the two superposed laminations form a V, like a chisel sharpened on both sides, although each individual lamination is sharpened only on one side. Such a construction could be used where the magnetic core is built up of laminations stacked two at a time. This embodiment is shown in the construction of Figs. 1 and 2.

In Fig. 3 I have shown a modified embodiment in which each individual lamination has its end sharpened or beveled on both sides on the edge which ends in a joint. Such a construction would be used on a core having laminations stacked one at a time, although of course, such a construction is not restricted to cores having laminations stacked one at a time.

The beveled edges of the laminations may have either a straight bevel or a curved bevel. The beveled edges may be obtained by grinding or cold-working the edges of the magnetic laminations.

In a further modification of my invention, I may increase the reluctance of the high density flux path by mutilating the edges of the jointed laminations in any manner at the places where the bevel would be made in the embodiments of Figs. 1 and 3. For example, by scoring the steel parallel to the joint edge on one or both sides of the laminations, this increased reluctance may be obtained.

There is shown in Fig. 4 a magnetic core, partially cut-away, having a leg member 5 and a yoke member 6. The respective layers are laid in an overlapping relation with respect to one another in the same manner as has been previously described for the core structure of Fig. 1. In order to obtain increased reluctance at the edges of the butt joints between the leg and yoke laminations, I score or groove each lamination in a direction parallel to the joint edge. Thus, grooves 7 are provided on both the leg and yoke laminations adjacent the edge of the joint in each laminar layer. This grooved surface achieves substantially the same effect as the beveled edges of Figs. 1, 2 and 3; namely, the grooved edges cause the flux approaching the joint in any given laminar layer to cross over to adjacent laminar layers before reaching the very edge of the butt joint, thus aiding in reducing the vibratory noise level of the core. The grooves 7 may be provided on one surface of each lamination, as shown in Fig. 4, or both surfaces may be grooved or scored.

There is shown in Fig. 5 a single lamination 8 which is scored or grooved in a different manner than shown in the construction of Fig. 4. In this modified arrangement, I provide a criss-cross pattern of scoring in which the edge of lamination 8 is provided with grooves 9 arranged in a criss-cross manner with respect to one another, rather than parallel to the joint edge. This criss-cross groove arrangement provides an increased reluctance at the outer edge of a laminar member where it is butt-jointed to another lamination, in a similar manner to the beveled edge construction of Figs. 1, 2 and 3.

As has been explained, in the embodiments of my invention shown in Figs. 1–5, inclusive, I reduce the permeability of the magnetic material adjacent the edges of the laminations by decreasing the laminar cross-sectional area adjacent the edges. I obtain this reduced cross-sectional area by a beveled edge construction in the embodi-

ments of Figs. 1–3, and by a grooved construction in the embodiments of Figs. 4 and 5.

However, it will be understood that I may reduce the permeability of the edges of the laminations in other ways than by reducing the cross-sectional area of the laminar edges. One way of reducing the permeability adjacent the laminar edges is to strain the magnetic material adjacent the edges. For example, the normal method of preparing magnetic laminations is to cut them to size and then anneal them. If the laminations are originally cut so that they are very slightly overlength and then annealed, and then afterwards cut to exact size, the strain introduced by the second cutting will decrease the permeability adjacent the laminar edges.

A different way of obtaining reduced permeability adjacent the laminar edges is to flex the material near the edges a plurality of times. Such flexing affects the magnetic characteristics of the metal in such way as to result in reduced permeability adjacent the edges.

A third way of reducing the permeability adjacent the laminar edges is to grind the surface of the lamination very slightly adjacent the edges, not sufficiently to produce any substantial deformation such as the beveled construction heretofore described, but sufficiently to strain the magnetic material and thereby reduce its permeability somewhat.

It will be seen that in all of the embodiments of my invention I have increased the magnetic reluctance of the lamination members adjacent the edge of a butt joint in order to cause magnetic flux in such laminated members to cross over to adjacent laminated layers before reaching the very edge of the butt joint. As has been explained, in constructions used in the prior art, the magnetic flux upon approaching a butt joint in a laminated magnetic core has always tended to pass to the very edge of the joint before crossing over to adjacent laminated layers. This fact explains to a large extent the vibration which occurs at the edge of such butt joints. In all of the embodiments of my invention, I have caused the magnetic flux to cross over to adjacent laminated layers before reaching the edge of the butt joints, and experiments which I have made justify the conclusion that such a construction reduces considerably the noise of vibration of the lamination members adjacent butt joints.

While I have illustrated the embodiments of my invention in connection with a plate type core comprised of stacked flat, rectangular-shaped laminations arranged in a plurality of stacks to form a rectangular-shaped core, it will be understood that my invention is not limited to use with such a core construction. My joint construction may be used with any core in which the joints for adjacent laminar layers or groups of laminar layers are overlapped with respect to adjacent laminar layers, or groups of laminar layers, respectively. Furthermore, my joint construction is not restricted to a simple two-step lap pattern as shown in Figs. 1 and 2, but may equally well be used with multi-step overlapped joint patterns.

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. A magnetic core for stationary electrical induction apparatus comprising a plurality of layers of laminated magnetic material, each of said layers having at least one butt joint therein where edges of magnetic material in the same layer come together, said plurality of layers being arranged in an overlapping relation with respect to one another so that all of said joints do not lie on the same cross-sectional line of said core, said respective layers having regions of increased magnetic reluctance immediately adjacent said butt-jointed edges so that a substantial portion of the magnetic flux approaching said butt-jointed edges will cross to adjacent overlapped laminations before reaching said butt-jointed edges, said regions of increased magnetic reluctance extending across substantially the entire magnetic flux flow path at the respective butt-jointed edges.

2. A magnetic core for stationary electrical induction apparatus comprising a plurality of layers of laminated magnetic material, each of said layers having at least one butt joint therein where edges of magnetic material in the same layer come together, said plurality of layers being arranged in an overlapping relation with respect to one another so that all of said joints do not lie on the same cross-sectional line of said core, said laminations of magnetic material having a reduced cross-sectional area adjacent butt-jointed edges as compared to the remaining portions of said laminations in order to increase the magnetic reluctance of said laminated material adjacent said edges so that a substantial portion of the magnetic flux approaching said butt-jointed edges will cross to adjacent overlapped laminations before reaching said butt-jointed edges, the thickness of said laminations across substantially the entire magnetic flux flow path at the respective butt-jointed edges being less than the thickness of said laminations elsewhere in said respective layers.

3. A magnetic core for stationary electrical induction apparatus comprising a plurality of layers of laminated magnetic material, each of said layers having at least one butt joint therein where edges of magnetic material in the same layer come together, said plurality of layers being arranged in an overlapping relation with respect to one another so that all of said joints do not lie on the same cross-sectional line of said core, said butt-jointed laminations being beveled across substantially the entire magnetic flux flow path along edges of intersection to increase the magnetic reluctance of said laminated magnetic material immediately adjacent said butt-jointed edges so that a substantial portion of the magnetic flux approaching said butt-jointed edges will cross to adjacent overlapped laminated layers before reaching said butt-jointed edges.

4. A magnetic core for stationary electrical induction apparatus comprising a plurality of layers of laminated magnetic material, each of said layers having at least one butt joint therein where edges of magnetic material in the same layer come together, said plurality of layers being arranged in an overlapping relation with respect to one another so that all of said joints do not lie on the same cross-sectional line of said core, said butt-jointed laminations being scored in close proximity to butt-jointed edges across substantially the entire magnetic flux flow path at said edges to increase the magnetic reluctance of said laminated magnetic material immediately

adjacent said butt-jointed edges so that a substantial portion of the magnetic flux approaching said edges will cross to adjacent overlapped laminated layers before reaching said butt-jointed edges.

5. A magnetic core for stationary electrical induction apparatus comprising a plurality of layers of laminated magnetic material, each of said layers having at least two laminar edges which are butt-jointed to one another, the plurality of laminated layers of said core being overlapped with respect to one another so that said joints do not all lie on the same cross-sectional line of said core, said laminated magnetic material having increased magnetic reluctance immediately adjacent said butt-jointed edges across substantially the entire magnetic flux flow path at said edges so that a substantial portion of the magnetic flux approaching said butt-jointed edges will cross to adjacent overlapped laminations before reaching said butt-jointed edges.

6. A magnetic core for stationary electrical induction apparatus comprising a plurality of layers of laminated magnetic material, each of said layers having at least two laminar edges which are butt-jointed to one another, the plurality of laminated layers of said core being overlapped with respect to one another so that said joints do not all lie on the same cross-sectional line of said core, said butt-jointed laminations being beveled along edges of intersection across substantially the entire magnetic flux flow path at said edges to increase the magnetic reluctance of said laminated material immediately adjacent said butt-jointed edges so that a substantial portion of the magnetic flux approaching said butt-jointed edges will cross to adjacent overlapped layers before reaching said butt-jointed edges.

7. A magnetic core for stationary electrical induction apparatus comprising a plurality of layers of laminated magnetic material, each of said layers having at least two laminar edges which are butt-jointed to one another, the plurality of laminated layers of said core being overlapped with respect to one another so that said joints do not all lie on the same cross-sectional line of said core, said butt-jointed laminations being scored in close proximity to butt-jointed edges across substantially the entire magnetic flux flow path at said edges to increase the magnetic reluctance of said magnetic laminated material immediately adjacent said butt-jointed edges so that a substantial portion of the magnetic flux approaching said butt-jointed edges will cross over to adjacent overlapped laminated layers before reaching said butt-jointed edges.

8. A magnetic core for stationary electrical induction apparatus comprising a plurality of layers of laminated magnetic material, each of said layers having at least two laminar edges which are butt-jointed to one another, the plurality of laminated layers of said core being overlapped with respect to one another so that said joints do not all lie on the same cross-sectional line of said core, said butt-jointed laminations being scored parallel to butt-jointed edges across substantially the entire magnetic flux flow path at said edges to increase the magnetic reluctance of said magnetic laminated material immediately adjacent said butt-jointed edges so that a substantial portion of the magnetic flux approaching said butt-jointed edges will cross over to adjacent overlapped laminated layers before reaching said butt-jointed edges.

9. A magnetic core for stationary electrical induction apparatus comprising a plurality of layers of laminated magnetic material, each of said layers having at least two laminar edges which are butt-jointed to one another, the plurality of laminated layers of said core being overlapped with respect to one another so that said joints do not all lie on the same cross-sectional line of said core, said butt-jointed laminations being scored across substantially the entire magnetic flux flow path at said edges in a criss-cross manner in close proximity to butt-jointed edges to increase the magnetic reluctance of said magnetic laminated material immediately adjacent said butt-jointed edges so that a substantial portion of the magnetic flux approaching said butt-jointed edges will cross over to adjacent overlapped laminated layers before reaching said butt-jointed edges.

10. A magnetic core for stationary electrical induction apparatus comprising a plurality of layers of laminated magnetic material, each of said layers having at least one butt joint therein where edges of magnetic material in the same layer come together, said plurality of layers being arranged in an overlapping relation with respect to one another so that all of said joints do not lie on the same cross-sectional line of said core, said butt-jointed laminations being beveled along both surfaces of butt-jointed edges to increase the magnetic reluctance of said laminated material immediately adjacent said butt-jointed edges so that a substantial portion of the magnetic flux approaching said butt-jointed edges will cross to adjacent overlapped laminated layers before reaching said butt-jointed edges, said edges being beveled across substantially the entire magnetic flux flow path at said joints.

11. A magnetic core for stationary electrical induction apparatus comprising a plurality of layers of laminated magnetic material, each of said layers having at least one butt joint therein where edges of magnetic material in the same layer come together, said plurality of layers being arranged in an overlapping relation with respect to one another so that all of said joints do not lie on the same cross-sectional line of said core, said butt-jointed laminations being beveled across substantially the entire magnetic flux flow path at butt-jointed edges to increase the magnetic reluctance of said laminated material immediately adjacent said butt-jointed edges so that a substantial portion of magnetic flux approaching said butt-jointed edges will cross to adjacent overlapped laminated layers before reaching said butt-jointed edges, the laminations in any given layer being beveled on one edge surface only, pairs of superposed laminations being laid together so that each pair of superposed beveled edges together form a V-shape.

HAROLD L. GARBARINO.

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