April 19, 1949. G. G. SOMERVILLE 2,467,867

ELECTROMAGNETIC INDUCTION APPARATUS AND METHOD OF FORMING SAME

Filed Sept. 11, 1944 2 Sheets-Sheet 1

Fig.1.

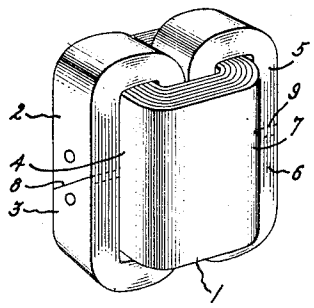



Fig.2.

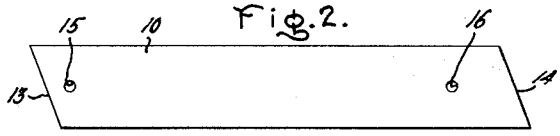



Fig.3.

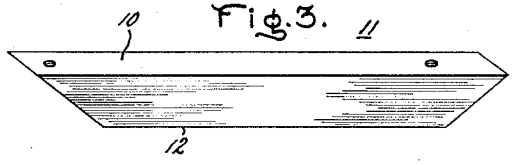



Fig.5.

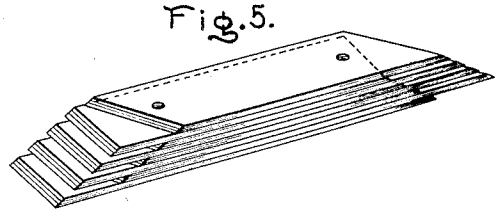


Fig.6.

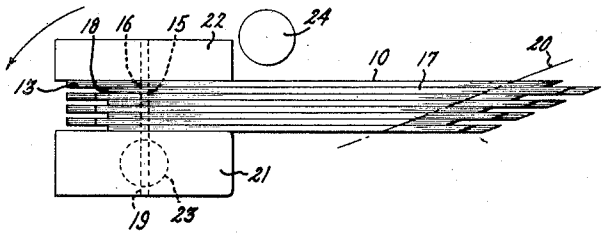



Fig.7.

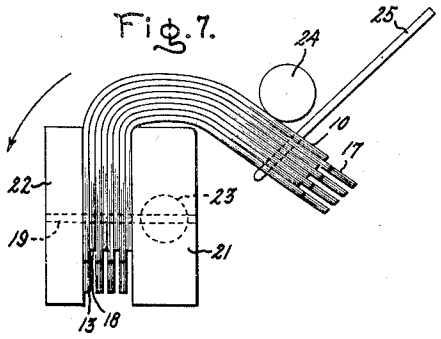



Fig.8.

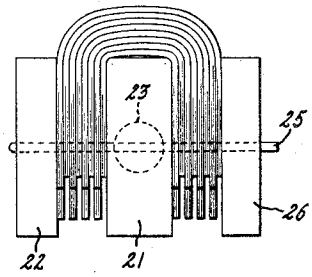
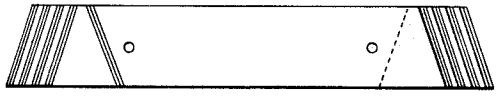



Fig.4.



Inventor:
Gareth G. Somerville,
by Harry E. Dunham
His Attorney.

April 19, 1949. G. G. SOMERVILLE 2,467,867

ELECTROMAGNETIC INDUCTION APPARATUS AND METHOD OF FORMING SAME

Filed Sept. 11, 1944 2 Sheets-Sheet 2

Fig. 9.

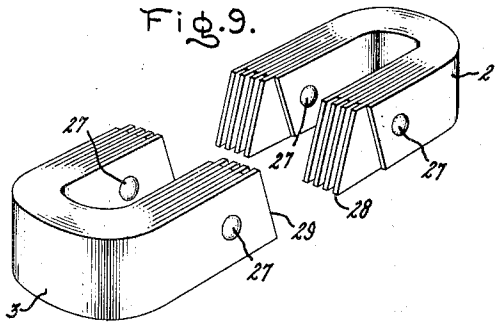



Fig. 10.

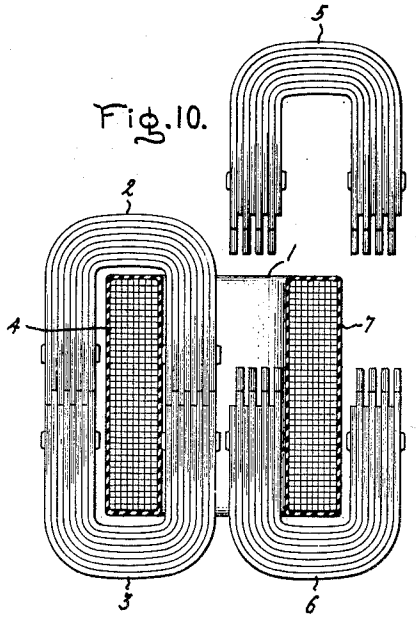



Fig. 11.

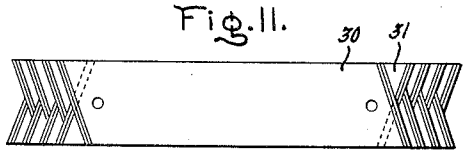



Fig. 12.

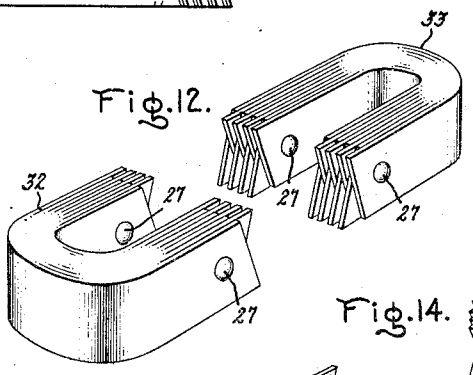



Fig. 13.

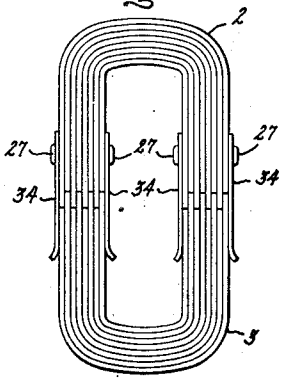
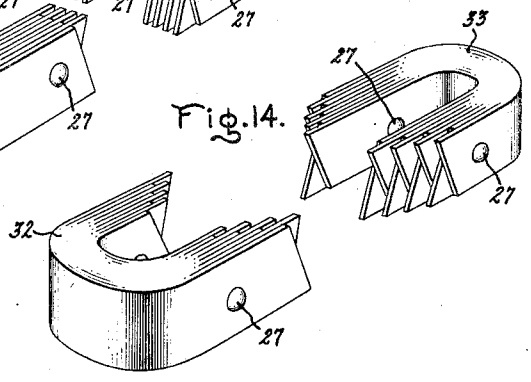



Fig. 14.




Inventor:
Gareth G. Somerville,
by Harry E. Dunham
His Attorney.

Patented Apr. 19, 1949 2,467,867

# UNITED STATES PATENT OFFICE

2,467,867

## ELECTROMAGNETIC INDUCTION APPARATUS AND METHOD OF FORMING SAME

Gareth G. Somerville, Pittsfield, Mass., assignor to General Electric Company, a corporation of New York

Application September 11, 1944, Serial No. 553,522

12 Claims. (Cl. 175—356)

1

My invention relates to electromagnetic induction apparatus, to a core of the curved iron type, and to methods of producing such a core and an assembled magnetic core and winding for such an apparatus.

Heretofore it has been known that an assembled electromagnetic induction apparatus including a preformed conductive winding structure and core therefor may be formed by providing two generally U-shaped core members of curved or bent strip of magnetic material and assembling the two U-shaped members with winding legs passing through the window of the conductive winding structure and a butt joint being provided between adjacent ends of the U-shaped core members. However, such a butt joint construction has a relatively high loss at the joints when compared with the loss in the remainder of the core structure even when pains are taken to cut a toroidally shaped wound core to produce a relatively good joint. A core may also be formed by assembling a plurality of magnetic sheets from two stacks to provide a pair of U-shaped core members and applying pressure to the assembled cores so that the adjacent ends of the sheets will provide a relatively tight butt joint. Such a core construction is described and claimed in my application Serial No. 538,303, filed June 1, 1944, and assigned to the same assignee as this present invention. In order to provide a still lower loss joint the sheets may be so cut as to provide a scarfed butt joint and also the sheets may be so assembled as to provide an overlapping scarfed butt joint. This overlapping may be accomplished by peripherally displacing adjacent sheets. Such a method of assembling magnetic sheets to provide a core of the curved iron type being described and claimed in my copending patent application Serial No. 536,748 filed May 22, 1944, now Patent No. 2,456,457, and assigned to the same assignee as this present invention.

However, as mentioned in both of my above-mentioned applications when two U-shaped core members are provided with an overlapping butt joint in the winding legs, unless the various layers are made sufficiently thick, some difficulty may be encountered in pushing the two U-shaped core members together as a unit so that the projecting ends fit into the desired place between adjacent ends of layers in the other U-shaped core member. For example, if a plurality of sheets are used of relatively thin material and an overlapped butt joint is desired in the winding leg then when the two U-shaped

2

members are pushed together in a direction substantially in the plane of the sheets in the leg, the ends may buckle rather than interfitting to provide a staggered or overlap butt joint.

It is therefore an object of my invention to provide an improved core construction of the curved iron type in which an overlap butt joint may be obtained within the winding leg which is efficient in operation and which may be conveniently and simply manufactured.

A further object of my invention is to provide an improved method of forming a core of the curved iron type.

A still further object of my invention is to provide an improved method of producing an assembled magnetic core and a conductive winding structure for an electromagnetic induction apparatus.

Further objects and advantages of my invention will become apparent from the following description referring to the accompanying drawing, and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

In the drawing Fig. 1 is a perspective view of an electromagnetic induction apparatus such as a transformer which is provided with an embodiment of my invention; Fig. 2 is a top view of one sheet which is employed in one of the core portions of Fig. 1; Fig. 3 is a stack of magnetic sheets which is employed to produce one of the U-shaped core members which forms one of the cores of Fig. 1; Fig. 4 is a stack of magnetic sheets of Fig. 3 being assembled to produce an overlap scarfed butt joint; Fig. 5 is a perspective view of the stack illustrated in Fig. 4; Fig. 6 is a view of the stack of magnetic sheets of Figs. 4 and 5 before the stack is bent to produce a U-shaped core construction; Figs. 7 and 8 illustrate the stack of magnetic sheets of Fig. 6 during steps in the production of a U-shaped core member; Fig. 9 is a perspective view of two U-shaped core members before being assembled around a conductive winding structure; Fig. 10 is a sectional side elevation of the transformer construction in Fig. 1 with one of the cores having been assembled around one winding leg and the other core during the process of assembly; Fig. 11 is a stack of sheets of magnetic material which is used to produce a modification of my invention; Fig. 12 illustrates two U-shaped core members which are produced from stacks of the type illustrated in Fig. 11; Fig. 13 is a sectional side elevation illustrating a modification of my

invention, and Fig. 14 illustrates my invention as applied to a scarfed butt joint.

Referring to Fig. 1 of the drawing I have illustrated an electromagnetic induction apparatus such as a transformer having a winding 1 with a core formed of generally U-shaped portions 2 and 3 surrounding a leg 4 of the winding and a similar core formed of core portions 5 and 6 surrounding another leg 7 of the conductive winding structure 1. Although two cores are provided around two legs of a conductive winding structure in Fig. 1 it will be understood that my invention may be employed with any suitable number of cores surrounding any suitable number of conductive winding structures.

As will be seen in Fig. 1, each of the core portions 2, 3, 5, and 6 is a generally U-shaped core portion and butt joints 8 and 9 of the type which will be described in detail below are provided between the core portions 2, and 3, and 5 and 6, respectively.

In order to produce the core portions illustrated in Fig. 1 I provide a plurality of sheets 10, one being shown in Fig. 2. These sheets of magnetic material may be formed of any suitable material such as highly directional strip steel having the most favorable magnetic direction running longitudinally of the sheets. Since a stack of sheets of the type illustrated in Fig. 2 are bent into the form of a U-shaped core member it will be understood that the layer at the outer perimeter of the core will be longer than the layer adjacent the inner perimeter of the core, the difference in length being proportional to the thickness of the core member. In order therefore to produce a joint construction 8 which runs generally in a direction perpendicular to the plane of the magnetic sheets in the legs of the U-shaped core members rather than producing a scarfed joint, the sheets are of progressively increasing length, that is the longest sheet will be at the outer periphery and the shortest sheet will be at the inner periphery. A stack of such sheets is illustrated in Fig. 3 and indicated generally by the numeral 11. Thus the longest sheet 10 is at the top of the stack and the shortest sheet 12 is in the bottom of the stack, and it will be understood that a designer given the size of the finished core may calculate the desired length of each of the sheets which will be used to produce the finished U-shaped core portion.

As has been mentioned above, when two U-shaped core members are assembled with a conductive winding structure and an overlap joint is provided, care must be taken during assembly in order to see that the adjacent ends of the sheets of the two U-shaped members return to their desired position. In order to provide a joint which will facilitate the assembly of two U-shaped core members having joints in the legs, the ends of the sheets are cut diagonally with respect to the longitudinal axis of the sheets and the sheets are also peripherally displaced so as to provide overlapping butt joints so that when the ends of the two U-shaped core members approach each other, angularly extending edges will be the first to become contiguous, and I have found that this thereby considerably facilitates the assembly of the core members. Referring to Fig. 2, it will be seen that the sheet 10 is provided with edges 13 and 14 which extend diagonally with respect to the longitudinal axis as well as extending diagonal with respect to the path of the most favorable magnetic direction of the sheet. It will be seen that the other sheets



in the stack illustrated in Fig. 3 also have edges which have planes which are parallel to the planes of the edges 13 and 14, the difference between the various sheets being that they are of progressively different lengths. These sheets may be formed in any suitable manner such as by cutting by hand from a strip or by cutting on a suitable index shearing machine such as of the type described in my copending application Serial No. 539,255, filed June 8, 1944, now Patent No. 2,369,617, and assigned to the same assignee as this present invention.

In order to stagger the adjacent edges of contiguous layers which produce the U-shaped core members the various layers or sheets are longitudinally displaced, as will be seen in Figs. 4 and 5. In order to facilitate this longitudinal displacement it will be seen that the magnetic sheet 10 in Fig. 2 is provided with holes 15 and 16 adjacent the opposite ends thereof. Furthermore, the holes 15 and 16 are spaced different distances from the adjacent edges, the hole 15 being relatively close to the edge 13 while the hole 16 is relatively further from the edge 14, and it will become apparent as the description proceeds that the difference between the distances of the holes 15 and 16 from their adjacent edges determines the amount of overlap between adjacent joints in the finished core. Furthermore, the various other sheets of the stack 11 are also provided with holes similar to the holes 15 and 16 with those holes also being a similar distance from the edges of those sheets as the holes 15 and 16 are from the edges 13 and 14, respectively of the sheet 10.

In order to stagger the joints the various sheets of the stack 11 are assembled by reversing adjacent sheets as will be illustrated in Figs. 4 and 5. Thus the sheet 10 will be assembled with its hole 16 at one end of the stack, for instance, at the left of the stack illustrated in Figs. 4 and 5, while the next adjacent sheet will be assembled with its hole 16 adjacent the right of the stack illustrated in Figs. 5 and 6. This will be seen more clearly in Fig. 6, in which the sheet 10 is provided with a hole 16 thereof adjacent the left of the stack while the next adjacent sheet 17 is provided with a hole 15 in registry with the hole 16. In this manner it will be seen that the sheets 10 and 17 are peripherally displaced, or an edge 13 of the sheet 10 overhangs an edge 18 of the sheet 17. It will be understood that the relative arrangements of the stacks illustrated in Figs. 4 and 5 are included for the sage of clarity, as it will be understood that in the production of the core members the sheets may be taken from a stack as illustrated in Fig. 3 and restacked directly into a stack as illustrated in Fig. 6. Any suitable number of sheets may be used to produce the layers 10 and 17 depending on the thickness of the sheets, and when 10 mil sheets are used three sheets in each layer is a suitable number.

In order to facilitate the stacking, the sheets may be stacked by passing a pin 19 through the adjacent holes. A dot dash line 20 is shown adjacent the opposite end of the sheets to illustrate how the holes at this end of the sheets line up when the sheets are stacked in the manner illustrated in Fig. 6.

In order to facilitate the bending or curving of the sheets into a substantially U-shaped core portion, adjacent ends of the sheets as is illustrated in Fig. 6 may be placed between mandrels 21 and 22, and with the mandrels 21 and 22 clamped tightly to the opposite sides of the stack.

The mandrel 21 may then be rotated on a shaft 23 and the sheets forced against a relatively stationary pin 24. Upon rotating the mandrel through approximately 90 degrees as is illustrated in Fig. 7, the sheets will be bent sufficiently so that a pin 25 may be passed through the holes at the free ends of the sheets. The sheets may be further bent then until the pin 25 extends through corresponding openings in the mandrels 21 and 22, at which time the pin 19 may be removed. A third mandrel 26 may then be clamped adjacent the remaining surface of the sheet so that the sheets are relatively tightly held in the manner as is illustrated in Fig. 8.

In order to remove the deleterious strains caused by the bending of the sheets as well as to give the sheets a permanent set in the position as is illustrated in Fig. 8, the bent sheets with the three mandrels may be placed in a furnace and annealed in this condition, or two U-shaped core members may be assembled and then annealed in this condition.

Upon removal of the sheets from the annealing oven rivets 27 may be placed in the holes of the sheets which are in registry so as to relatively tightly hold the sheets in the same relative position which they had when they were removed from the annealing oven.

In order to assemble the U-shaped core portions with the conductive winding structure 1 they may be passed through the windows in the manner illustrated in Fig. 10. Thus the U-shaped core portions 2 and 3 have been assembled around the legs 4 of the winding 1 while the U-shaped core portions 5 and 6 are in the process of being assembled around the winding leg 7.

I have found that when core portions of the type illustrated in Fig. 10 are assembled with a preformed conductive winding structure, that since the edges of the adjacent sheets of the two core portions are angularly arranged with respect to each other, when the sheets are pushed together in a direction parallel with the planes of the sheets in the legs, the extending corners 28 and 29 will be the first to become contiguous, as will be seen from an inspection of Fig. 9, and I have found that it is much easier to assemble such U-shaped core portions to provide an overlap joint when diagonally extending edges are the first to come together.

In the cores described above, the adjacent sheets are longitudinally displaced so that the corresponding ends of adjacent sheets of each of the U-shaped core members are spaced from each other. It will be understood, however, that the corresponding edges of the adjacent sheets may be placed in any suitable relationship to each other, and in Fig. 11 I have illustrated a stack of sheets of magnetic material in which the sheets are so stacked that the adjacent edges of the sheets cross each other in the vicinity of the middle of each of the sheets. The stack of sheets illustrated in Fig. 11 are formed of sheets similar to that illustrated in Fig. 3 except that the holes are placed the same distance from the adjacent edges rather than different distances as is illustrated in Figs. 2 and 3. Thus a layer 30 is provided and the adjacent layer 31 is similar to the layer 30 except that it is laterally reversed, or flopped over. It will be understood, of course, that the layer 31 is slightly longer than the layer 30 in order to produce joints which run generally from the inner surface of the final core to the outer surface in the same general plane. The layers 30 and 31 may include any suitable number of sheets.



The stack of sheets of Fig. 11 may be bent in mandrels in the same manner as described above in connection with Figs. 6, 7 and 8, so as to produce a core portion 32 as is illustrated in Fig. 12. Fig. 12 also illustrates a similar core portion 33. The cores, of course, after they have been bent to the position to assume the shape they will have in the finished apparatus may be annealed and after removal of the strain relief anneal may be assembled around a conductive winding structure. The cores may also be assembled, annealed, and then disassembled and reassembled around a conductive winding structure.

In Fig. 13 I have illustrated the core portions 2 and 3 except that guide members are placed adjacent the inner and outer surfaces of each of the legs of the U-shaped core portion 2. These guide members 34 may be formed of any suitable material such as steel and they may be supported through the rivets 27. It will be understood that when the core portions 2 and 3 are assembled around the leg 4 of the conductive winding structure that the guide members 34 will facilitate the assembly so that the adjacent ends of the sheets of the two U-shaped portions will be placed in the desired relative positions as illustrated in Fig. 13.

In Fig. 14 I have illustrated a core construction having the same general type of joint as that shown in Fig. 12 except that the joint progresses diagonally from the inner layer to the outer layer rather than progressing in the same general planes. This type of scarfed butt joint is obtained by providing two groups of magnetic sheets of suitable lengths and for one type of scarfed joint one group of sheets may have progressively different lengths and the other group the same length. The core of the type shown in Fig. 14 may be formed and assembled in the manner described above in connection with Figs. 1 through 10.

Although I have shown and described particular embodiments of my invention, I do not desire to be limited to the particular embodiments described, and I intend in the appended claims to cover all modifications which do not depart from the spirit and scope of my invention.

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

1. The method of forming a core of the curved iron type for an electromagnetic induction apparatus including the steps of cutting from a strip of magnetic material a plurality of accurately precut length sheets with edges diagonal with the longitudinal axis of the sheets, assembling the sheets into a stack so that adjacent ends of sheets are angularly arranged with respect to each other and flatwise bending the sheets so that the stack has the configuration of the finished core.

2. The method producing an assembled magnetic core and winding for an electromagnetic induction apparatus including the steps of cutting a magnetic strip diagonally crosswise with respect to the longitudinal axis of the strip into a plurality of sheets, assembling the sheets into two packets in which certain of the sheets are reversed end for end relative to the others, and forming them into a pair of generally U-shaped core portions, annealing the core portions, and assembling the U-shaped core portions with a coil winding structure and with corresponding

diagonally cut ends of sheets of the core portions substantially abutting each other to form a close core around the coil winding structure.

3. The method of producing an assembled magnetic core and winding for an electromagnetic induction apparatus including the steps of cutting a magnetic strip diagonally crosswise with respect to the longitudinal axis of the strip into a plurality of sheets, stacking the sheets into a pair of stacks by reversing adjacent sheets of each stack, flatwise bending said stacks into curved core portions, annealing the pair of stacks, and assembling with a coil winding structure with corresponding diagonally cut ends of sheets of the stacks substantially abutting each other to provide a relatively low loss joint between the stacks.

4. The method of producing an assembled magnetic core and winding for an electromagnetic induction apparatus including the steps of cutting magnetic strip material diagonally crosswise with respect to the longitudinal axis of the strip into a plurality of sheets with adjacent cuts substantially parallel to each other, stacking the sheets into a pair of stacks by reversing adjacent sheets of each stack, flatwise bending said stacks into curved core portions, annealing the pair of stacks, and assembling with a coil winding structure with corresponding diagonally cut ends of sheets of the stacks substantially abutting each other to provide a relatively low loss joint between the stacks.

5. The method of producing an assembled magnetic core and winding for an electromagnetic induction apparatus including the steps of cutting magnetic strip material diagonally crosswise with respect to the longitudinal axis of the strip into a plurality of sheets, stacking the sheets into a pair of stacks by reversing and longitudinally displacing adjacent sheets of each stack, flatwise bending said stacks into curved core portions, annealing the pair of stacks, and assembling with a coil winding structure with corresponding diagonally cut ends of the sheets of the stacks substantially abutting each other to provide a low loss butt overlapped joint between the stacks.

6. The method of producing an assembled magnetic core and winding for an electromagnetic induction apparatus including the steps of cutting magnetic strip material diagonally crosswise with respect to the longitudinal axis of the strip into a plurality of sheets, providing adjacent cuts substantially parallel to each other, stacking the sheets into a pair of stacks by reversing and longitudinally displacing adjacent sheets of each stack, flatwise bending said stacks into curved core portions, annealing the pair of stacks, and assembling with a coil winding structure with corresponding diagonally cut ends of the sheets of the stacks substantially abutting each other to provide a low loss butt overlapped joint between the stacks.

7. The method of producing an assembled magnetic core and winding for an electromagnetic induction apparatus including the steps of cutting magnetic strip material diagonally crosswise with respect to the longitudinal axis of the strip into a plurality of sheets, providing adjacent cuts substantially parallel to each other, stacking the sheets into a pair of stacks by reversing adjacent sheets of each stack, forming the stacks into a pair of generally U-shaped core portions, annealing the core portions, and assembling the U-shaped core portions with a coil winding structure by pressing the ends of the U-shaped core portions so that adjacent sheets come together with the angularly cut ends becoming contiguous.

8. The method of forming a core for an electromagnetic induction apparatus including the steps of cutting magnetic strip material into a plurality of sheets, providing the sheets with holes in the vicinity of the ends of the sheets and with the holes adjacent opposite ends of the sheets different distances from the adjacent ends, stacking the sheets by longitudinally reversing groups of adjacent sheets and aligning holes of the sheets adjacent one end of the stack, passing a pin through said aligned holes, and flatwise bending said sheets into their final shape in said core.

9. The method of making a laminated magnetic core with a low reluctance joint which is easily opened and closed including the steps of providing a plurality of different length strips of magnetic material whose ends are all cut on the same bias angle, stacking said strips in the order of their length with alternate groups of adjacent strips reversed so that their ends are at an angle with each other, simultaneously flatwise bending said strips into the final shape they will have in said core, and setting said strips in that shape by strain relief annealing them.

10. In a normally closed bent iron magnetic core, at least one core joint between parallel core sections which is openable as a unit for the purpose of linking said core with a preformed conducting winding, said core joint being a series of staggered butt joints between ends of the core laminae, the even-numbered butt joints being parallel with each other, the odd-numbered butt joints being parallel with each other and making an angle with the even-numbered butt joints whereby closure of said core joints is facilitated by initial point contact of overlapping laminae, the odd- and even-numbered butt joints extending diagonally in one continuous straight line across the ends of their respective laminae at equal and opposite angles relative to the center lines of the laminae, the odd- and even-numbered butt joints crossing each other at the longitudinal center line of their respective laminations, the crossing points of successive butt joints progressing circumferentially and through said core.

11. In a normally closed laminated bent iron magnetic core, at least one core joint between parallel core sections which is openable as a unit for the purpose of linking said core with a preformed conductive winding, said core joint being a series of staggered unbroken straight line butt joints between ends of the core laminae, adjacent ones of said butt joints making different angles with the center line of their respective laminae whereby closure of said joint is facilitated by initial point contact of overlapping laminae, each of said staggered butt joints including a plurality of adjacent superposed laminations.

12. In a normally closed bent iron magnetic core, at least one core joint between parallel core sections which is openable as a unit for the purpose of linking said core with a preformed conducting winding, said core joint being a series of staggered butt joints between ends of the core laminae, the even-numbered butt joints being continuous straight line parallel with each other, the odd-numbered butt joints being continuous straight line parallel with each other and making an angle with the even-numbered butt joints whereby closure of said core joints is fa-

cilitated by initial point contact of overlapping laminae, each of said odd- and even-numbered butt joints including a plurality of adjacent superposed laminations.

GARETH G. SOMERVILLE.


REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 511,574 | Wood | Dec. 26, 1893 |
| 581,873 | Thomson | May 4, 1897 |
| 970,587 | Wiemer | Sept. 20, 1910 |
| 1,102,513 | Johannesen | July 7, 1914 |
| 1,285,996 | Hensley | Nov. 26, 1918 |
| 1,318,044 | Bechman | Oct. 7, 1919 |
| 1,365,569 | Troy | Jan. 11, 1921 |
| 1,935,426 | Acly | Nov. 14, 1933 |
| 2,214,673 | Hauser | Sept. 10, 1940 |
| 2,252,461 | Franz | Aug. 12, 1941 |
| 2,274,519 | Barrett | Feb. 24, 1942 |
| 2,293,951 | Seastone | Aug. 25, 1942 |
| 2,305,650 | Vienneau | Dec. 22, 1942 |
| 2,305,686 | Franz | Dec. 22, 1942 |
| 2,348,003 | Granfield | May 2, 1944 |

FOREIGN PATENTS

| Number | Country | Date |
|---|---|---|
| 2,767 | Great Britain | 1872 |
| 7,856 | Great Britain | 1889 |
| 106,986 | Great Britain | June 14, 1917 |