

Dec. 14, 1948.

G. G. SOMERVILLE
ELECTROMAGNETIC INDUCTION APPARATUS
AND METHOD OF FORMING SAME

2,456,458

Filed May 22, 1944

2 Sheets-Sheet 1

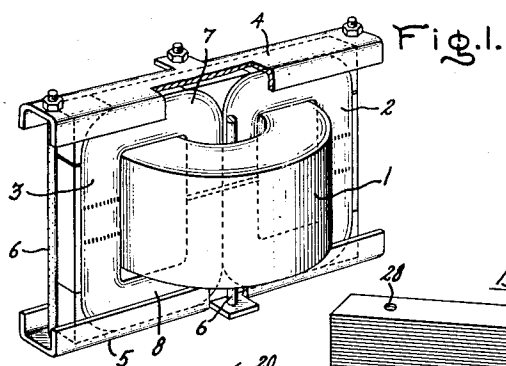


Fig. 2.

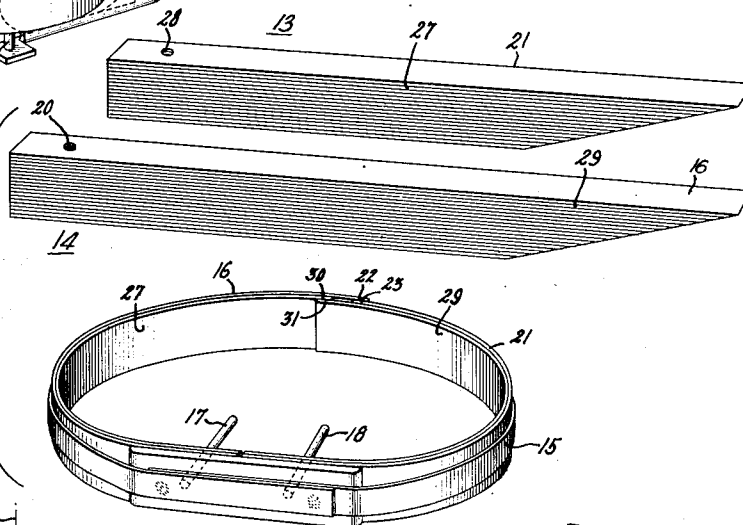


Fig. 3.

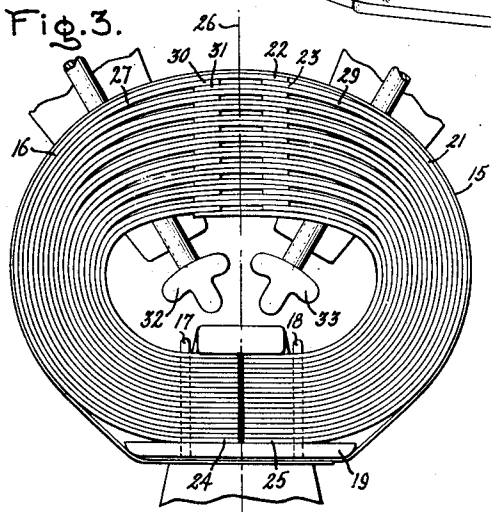


Fig. 4.

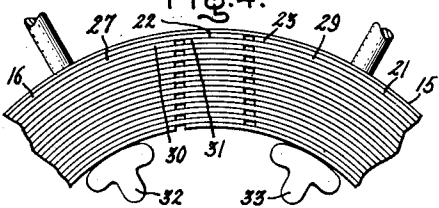
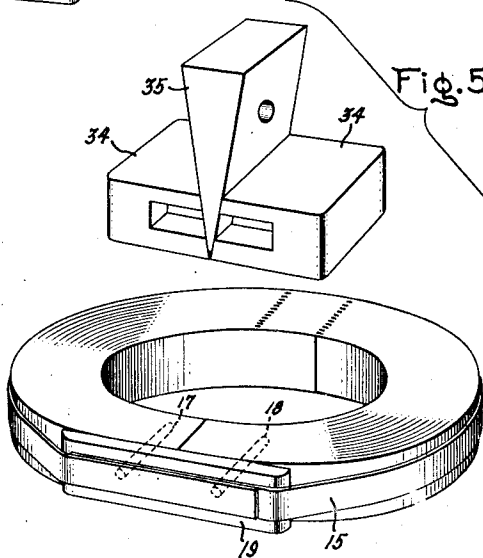


Fig. 5.



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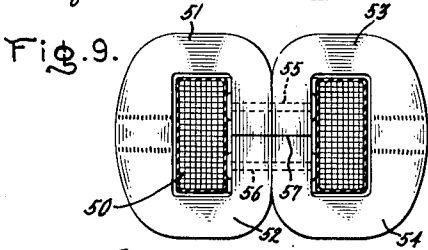
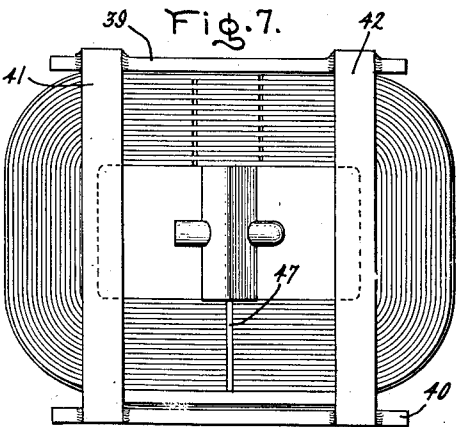
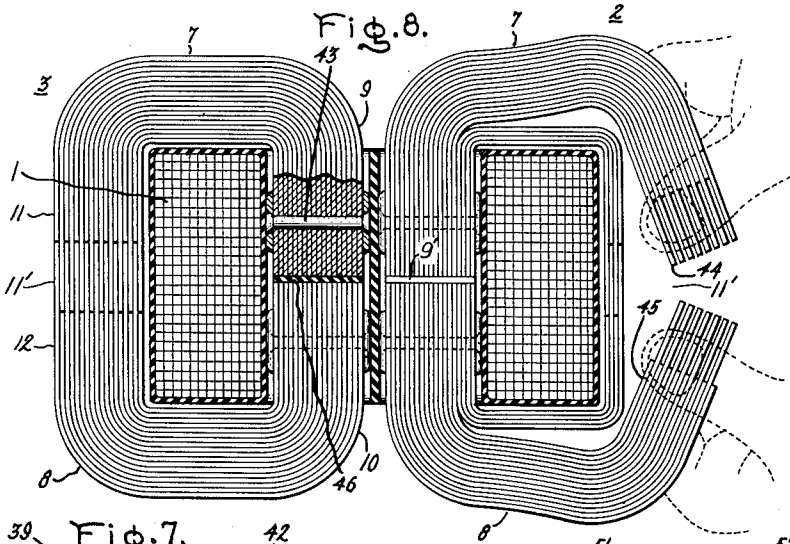
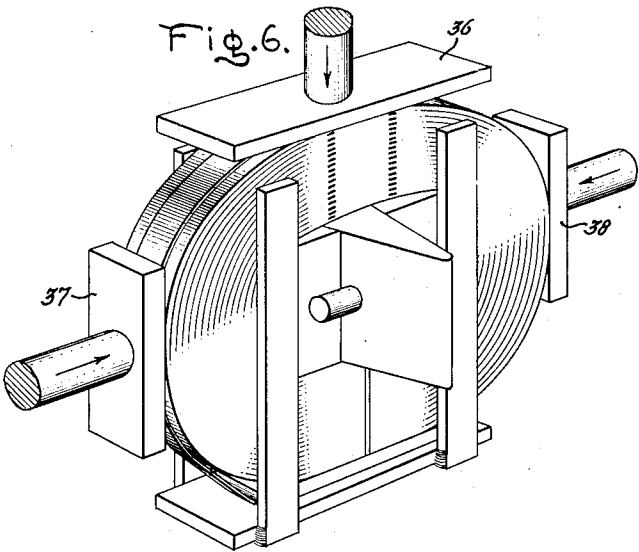
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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ELECTROMAGNETIC INDUCTION APPARATUS AND METHOD OF FORMING SAME

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Application May 22, 1944, Serial No. 536,749

7 Claims. (Cl. 29—155.61)

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

Electromagnetic induction apparatus have been formed with cores of a plurality of assembled flat punchings, or of a curved or bent strip of magnetic material, or of bonded powdered iron. The powdered iron type core has usually been used in high frequency apparatus, the wound core type has been used in the smaller distribution type transformers, and the flat laminated type has been used in the larger distribution transformers and power transformers.

In my application S. N. 536,748, filed concurrently herewith and assigned to the same assignee as this present invention, I have described and claimed a curved iron type core for electromagnetic induction apparatus which may be efficiently applied to a relatively wide range of transformer sizes. This curved iron type core includes generally the use of a plurality of sheets of magnetic material formed of magnetic strip having the most favorable magnetic direction in line with the flux path and assembling the sheets, which sheets are assembled and given the shape the core will have in the finished apparatus. The core is then annealed in this position, and assembled around a preformed conductive winding structure with a minimum of flexure of the magnetic sheets. My improved curved iron type core and method of forming the core which forms the subject matter of the present application may be employed to produce any suitable type of joint construction, and in certain types of electromagnetic induction apparatus, such as reactors, it is desirable to have both an air gap and an overlapped or staggered butt joint, and it is therefore a general object of my invention to provide an improved electromagnetic induction apparatus which will have an air gap in one leg and an overlap joint in another leg.

A further object of my invention is to provide an improved method of forming a curved iron type core for an electromagnetic induction apparatus.

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

Further objects and advantages of my invention will become apparent from the following

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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.

Referring to the drawings, Fig. 1 illustrates a perspective view of a transformer which is provided with an embodiment of my invention; Fig. 2 is a perspective view of the two groups of magnetic sheets to form each of the cores of Fig. 1, and a ring within which the sheets from each of the groups are assembled; Fig. 3 illustrates the laminations assembled in the ring of Fig. 2; Fig. 4 is a fragmentary view of the magnetic sheets expanded with the adjacent ends of the laminations in general abutting relation; Fig. 5 is an exploded perspective view of the assembled magnetic sheets and the form used to expand the core; Fig. 6 illustrates the core during a further step in giving the core the shape it will have in the finished apparatus; Fig. 7 is a side view of the core in the shape it has when inserted into an annealing furnace; Fig. 8 illustrates the reactor of Fig. 1 with one core assembled around one of the legs of the winding and the other core in the process of being assembled, and Fig. 9 illustrates an electromagnetic apparatus with the sheets having a modified joint construction.

Referring to Fig. 1 of the drawings, I have illustrated an electromagnetic induction apparatus including a preformed conductive winding structure 1 with cores 2 and 3 passing through the window of the winding and surrounding legs thereof. A core clamp is provided in the form of U-shaped bars 4 and 5 which are placed on either side of the cores and forced together by bolts 6.

In the construction illustrated in Fig. 1, two cores are provided with legs passing through the winding window, but it is to be understood that any suitable number of cores may be employed. As will be seen more clearly in Fig. 8, each of the cores 2 and 3 includes two U-shaped core portions 7 and 8 with air gaps 9' between the adjacent ends of the leg portions 9 and 10 within the winding window and overlapping or staggered butt joints 11' between the outer leg portions 11 and 12. Such a construction may be employed with any suitable type of electromagnetic induction apparatus but this construction has particular application to a reactor. Since each of the cores 2 and 3 are similar, only one will be described below in connection with Figs 2 through 7.

In order to produce the magnetic core 2, I provide two groups of sheets of magnetic material, the groups being indicated generally by the numerals 13 and 14 in Fig. 2. The magnetic sheets may be formed in any suitable manner such as by cutting from magnetic strip material having the most favorable magnetic direction longitudinally of the strip. Furthermore, as will be seen from Fig. 2, the magnetic sheets are cut of progressively different lengths. Thus given the size of the core, its configuration in the completed apparatus and the relative position of the joints, the peripheral distance of each of the sheets for the layer may be determined. The sheets may be cut by hand to the predetermined length or they may be cut on an index shearing machine of the type described and claimed in my patent application S. N. 539,255, filed June 8, 1944, now patent No. 2,369,617, and assigned to the same assignee as this present invention.

The groups of sheets 13 and 14 illustrated in Fig. 2 may be assembled in any suitable manner to produce my improved core and I have illustrated in Fig. 2 a band 15 into which the sheets may be assembled to produce the core. The machine including this band upon which the laminations are assembled is described in further detail in my application S. N. 536,748, which has been referred to above.

In order to assemble the various sheets from the groups 13 and 14 into the band, the longest sheet 16 from the group 14 is inserted inside the band by bending it sufficiently so as to generally follow the contour of the inside surface of the band. In order to facilitate assembly of the various sheets inside the band 15, pins 17 and 18 are anchored in plate 19 and extend inward. It will also be seen that the various sheets which make up the group 14 each have an opening 20 positioned slightly from one end thereof. Thus upon introduction of the sheet 16 within the band the pin 17 is passed through the opening 20. A corresponding sheet 21 of the group 13 is then removed and introduced into the band 15 so that in the finished core the sheet 16 from the group 14 and the corresponding sheet 21 from the group 13 will make one complete layer. Referring to Fig. 4, it will be seen that an end 22 of the sheet 16 will abut the corresponding end 23 of the sheet 21. However, for convenience in assembly the ends 22 and 23 of the sheets 16 and 21, respectively, are allowed to stay in overlapping relation until any suitable number are assembled. The sheets, however, may be made to have the ends 22 and 23 butt against each other by expanding and curving them sufficiently when they are inserted within the ring.

As will be seen, particularly in relation to Figs. 3 and 4, the total length of the sheets 16 and 21 make up one complete layer with the ends 22 and 23 in abutting relation, and the opposite ends 24 and 25 also in abutting relation or with a gap therebetween, as desired. It will be noted, however, that the ends 22 and 23 are not placed directly opposite the gap between the ends 24 and 25, and assuming that the gap made by the ends 24 and 25 will be in approximately the center of the leg 9-10, the joint between the ends 22 and 23 as shown in Figs. 3 and 4 will be displaced slightly to the right of the center line 26. The joint between the ends 22 and 23 may be displaced any suitable amount by merely varying the relative lengths of the sheets 16 and 21, and in the construction illustrated in Fig. 3 the sheet 16 is longer than the sheet 21 by the amount in

which the joint between the ends 22 and 23 extends to the right of the center line 26.

In order that the joints in the outside leg made of the portions 11 and 12 will be staggered so as to provide overlapping butt joints, while the joints between the inner leg portions 9 and 10 will all be in registry so as to provide a straight gap, the next layer formed of sheets adjacent the sheets 16 and 21 will be so formed that a sheet from the group 13 will be placed contiguous with sheet 16 of the group 14. Thus referring to Fig. 2, a sheet 27 is taken from the group 13 which is the next shorter sheet of the group 13 adjacent the sheet 21 and introduced into the ring with the pin 17 passing through the opening 28, and the sheet 27 extending around the ring to the left looking at Fig. 3 and adjacent the sheet 16. Similarly, a sheet 29 is taken from the group 14 and introduced into the ring with a pin 18 passing through the opening 20 of the sheet and the sheet extending around to the right adjacent the sheet 21. Since the sheet 29 is longer than sheet 27 by the same amount that the sheet 16 is longer than the sheet 21, the ends 30 and 31 of the sheets 27 and 29, respectively, will in the finished core provide a butt joint to the left of the center line 26 as will be seen in Fig. 4. Thus providing a closed magnetic core by assembling sheets from two groups in which the sheets of one group are slightly longer than one-half the periphery and the corresponding sheets of the other group being slightly less than one-half the periphery and with the sheets of each group being assembled alternately, an overlap butt joint will be provided in one of the legs. Since the holes 20 and 28 are provided the same distance from the adjacent ends of the sheets it will be seen that in the opposite leg the various ends of the sheets will be placed in registry so as to provide either a butt joint or a straight sided gap across the leg 11-12 of the finished core.

After all the sheets have been introduced as is illustrated in Fig. 3 and described above, the various overlapping ends may be placed in abutting relation by applying pressure to fingers 32 and 33 in the manner described in my application S. N. 536,748. This will cause the ends to be pulled slightly apart in the manner as shown in Fig. 4 after which they may be forced together so as to provide a relatively tight butt joint between the adjacent ends of the sheets from each of the groups. Instead of stacking one sheet at a time from each group, any other suitable number from each group may be stacked at one time.

The core may then be used in a circular form or it may be expanded by using an expansion type wedge, as is illustrated in Fig. 5, including two similar blocks 34 with a wedge member 35. The introduction of the wedge shaped mandrel in the position as illustrated in Fig. 5 and then the forcing of the wedge 35 into the position as is illustrated in Fig. 6, will elongate the core. However, since the joints are placed in opposite legs the use of the expansion mandrel may cause the joints to open up, and in order to complete the expanding operation as well as to cause the adjacent ends of the sheets to fit relatively tightly together the core may be introduced into a press, one leg of the core being put on a base of the press and the press having movable pistons 36, 37 and 38. Thus by pressing on the core from four opposite sides the core may be given the oblong configuration as is illustrated in Fig. 7. In order to hold the core in this position a bracket is placed around the core having plates 39 and 40 which are

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held tightly on either side of the core by means of bars 41 and 42, which may be attached to the plates in any suitable manner such as by spot welding. In order to remove all deleterious strains and give the sheets a permanent set in the position they will have in the final core, the core construction as illustrated in Fig. 7 may be placed in an oven and given a suitable strain-relief anneal.

In order to assemble the core around the leg of a preformed conductive winding structure the brackets 39 and 40 are removed and the U-shaped core portions disassembled by pulling them apart by applying force to the U-shaped members 7 and 8 in the opposite directions, which force will be parallel with the longitudinal axis of the core. Rivets 43 may be introduced through the holes so as to relatively tightly hold the adjacent ends of the sheets together. The two U-shaped portions 7 and 8 are then assembled with the preformed coil winding structure 1 by projecting the legs 9 and 10 into the winding window with their ends forming an air gap or a registering butt joint. Upon holding the ends in the desired relation inside the winding window the outer ends of the core are pulled outwardly in any suitable manner such as by grasping with hands, as is illustrated diagrammatically in Fig. 8. The laminations are then allowed to slip back into position by allowing first one lamination from the core portion 7 and then the corresponding sheets from the core portion 8 to drop into place. Thus a longer sheet 44 from the core portion 7 is allowed to drop into place and then the corresponding shorter sheet 45 from the core portion 8 until the ends are in abutting relation as is illustrated in Fig. 8. The various sheets are then allowed to slip back into place until the core takes the position as is illustrated by the core 3 in Fig. 8, which core is shown as already assembled around the conductive winding structure. It will also be noted that a strip of insulating material 46 has been placed between the adjacent ends 9 and 10 of the leg portions so as to fix the length of the air gap but it is to be understood that the ends may be placed in abutting relation without the insulating sheet if desired. In order that the ends may not be strained with the use of the layer 46 the core before anneal has a metal piece 47 of the same dimensions as the sheet 46 between the leg portions 9 and 10.

In Fig. 9 I have illustrated a modification of my invention including a preformed winding 50 which is assembled with two cores including U-shaped portions 51 and 52 which form one core and U-shaped portions 53 and 54 which make up the other core. In the construction illustrated in Fig. 9, rivets 55 and 56 tightly hold together the adjacent sheets of both of the cores which make up the legs which project into the winding window. Thus the cores are assembled with the preformed coil by introducing the U-shaped members 51 and 53, and 52 and 54 from opposite directions to form the gap or butt joint 57 and then forming the overlap butt joint in the outer legs in the same manner described above in connection with Fig. 8. It will also be seen that in the construction illustrated in Fig. 9 there is a build-up on the two outer legs in the vicinity of the joints and this particular joint is more completely described in my application S. N. 553,523, filed September 11, 1944, and assigned to the same assignee as this present invention.

Although I have shown and described particular embodiments of my invention, I do not desire

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to be limited to the 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 producing an assembled magnetic core and winding for an electromagnetic induction apparatus including the steps of cutting from magnetic strip material at least two groups of sheets each having a length less than the total length of the perimeter of the finished core and with the lengths of the sheets of each group having progressively different lengths, assembling the sheets of both groups to provide a closed core of a plurality of layers and providing the longer sheets of each group at the outer periphery with each layer including one sheet from each group and with the sheets of each group being assembled alternately, aligning the ends of the sheets to provide aligned joints in one portion of the core and staggering the opposite ends to provide staggered butt joints in another portion of the core, applying pressure at both the inside and outside surfaces of the assembled core structure so as to abut relatively closely adjacent ends of the sheets of each layer and to provide a relatively tight laminated structure with the shape the core will have in the finished apparatus, annealing the core, and disassembling the groups of sheets into two core portions and reassembling the two core portions around the winding.

2. The method of producing an assembled magnetic core and winding for an electromagnetic induction apparatus including the steps of cutting from magnetic strip material two groups of sheets having progressively different lengths with the corresponding sheets of one group having a length slightly more than one-half the total perimeter and the corresponding sheet of the other group having a length slightly less than one-half the perimeter of the core at a predetermined layer in the assembled core structure, and assembling the sheets of both groups to provide a plurality of layers and providing the longer sheets of each group at the outer perimeter with each layer including one sheet of each group and with adjacent sheets being from different groups so as to stagger the butt joints at at least one side of the core, applying pressure at both the inside and outside surfaces of the assembled core structure so as to abut relatively closely adjacent ends of the sheets of each layer and provide a relatively tightly laminated structure with the shape the core will have in the finished apparatus, annealing the core, and disassembling the groups of sheets into two core portions and reassembling the two core portions around the winding.

3. The method of providing a core for an electromagnetic induction apparatus including the steps of providing two groups of sheets of magnetic material, the corresponding sheets of each group having different lengths and the total length of any two corresponding sheets of the groups being equal to the total perimeter of the assembled core at a predetermined layer, and assembling one sheet from each group with ends in predetermined spaced relation to provide a layer, and assembling an adjacent layer of one sheet from each group with ends in predetermined spaced relation and with the sheets of one group lying contiguous with the sheets of the other group.

4. The method of forming a core for an electromagnetic induction apparatus including the steps of providing two groups of sheets of magnetic material of progressively different lengths, with corresponding sheets of each group having different lengths and with holes spaced the same distance from one end of the sheets, and assembling a plurality of sheets from each group so that one sheet from each group forms a layer in the finished core and aligning holes of contiguous sheets so that the ends provide a smooth faced gap in one portion of the core, the assembling step including placing sheets from both groups contiguously so that ends of adjacent sheets will overlap in another portion of the core.

5. The method of producing an assembled magnetic core and winding for an electromagnetic induction apparatus including the steps of providing two groups of sheets having progressively different lengths with the corresponding sheets of one group having a length slightly more than one-half the total perimeter and the corresponding sheet of the other group having a length slightly less than one-half the perimeter of the core at a predetermined layer in the assembled core structure, assembling the sheets with one sheet from one group adjacent a sheet from the second group with the longer sheets at the outer perimeter so as to provide a core with aligned joints in one leg and staggered butt joints in the other leg, annealing the core, disassembling the core into two U-shaped core portions, placing the legs of the U-shaped portions having the aligned joints in a winding window, and slightly flexing the sheets of the outer leg so as to place the adjacent sheets of the core portions with overlapping ends and in the position subsequent to anneal.

6. The method of providing a core for an electromagnetic induction apparatus including the steps of providing two groups of sheets of magnetic material of progressively different lengths, and assembling one sheet from each group to form at least a portion of a layer of the core, and forming at least a portion of an adjacent layer by assembling one sheet from each group

and with the sheet of one group in one layer lying contiguous with the sheet from the other group in the adjacent layer.

7. The method of linking a conductive winding with a magnetic core which comprises building up a laminated magnetic loop from a plurality of bent magnetic strips in which each layer consists of two unequal length strips, providing a substantially equal registering gap between one pair of ends of the strips in each layer, providing a butt joint between the other pair of ends of the strips in each layer, reversing the inequality in length of said strips in certain of said layers so as to stagger said butt joints, mechanically forcing said loop into a generally rectangular shape with said gap in one straight leg and said staggered butt joint in the opposite straight leg, annealing said core, separating said core at said gap and butt joints into two U-shaped members, placing the legs of said members whose ends form said gap into the window of said conductive winding from opposite sides thereof, and flexing the other legs of said members so as to interleave said strips and reform said staggered butt joints.

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