

Sept. 17, 1946.

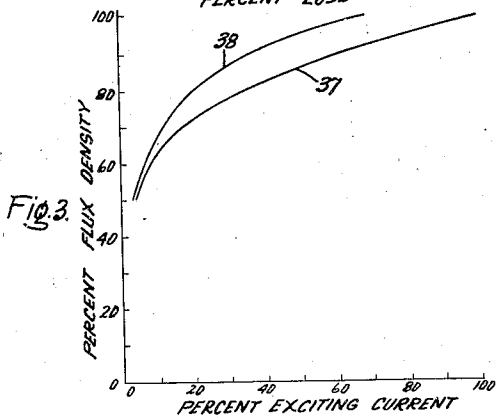
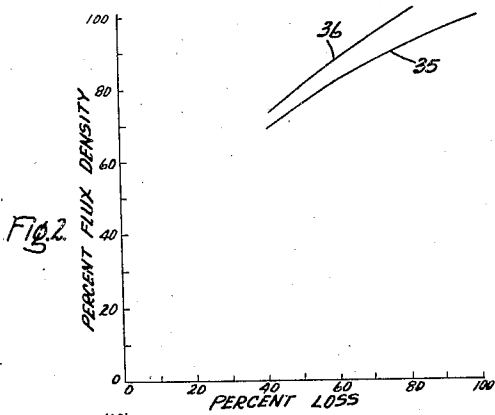
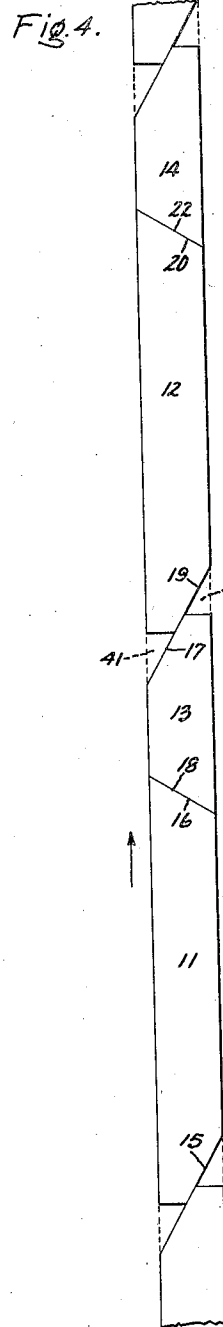
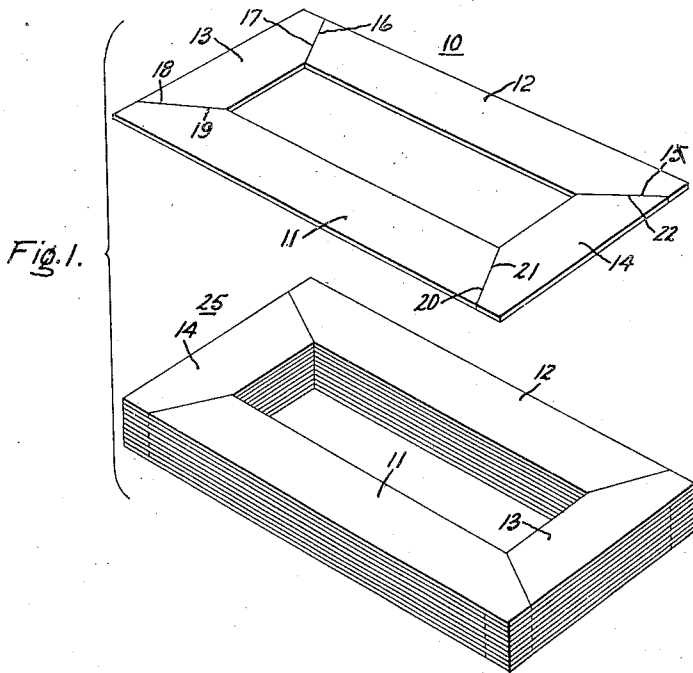
I. H. SCLATER

2,407,688

MAGNETIC CORE

Filed Dec. 30, 1942

2 Sheets-Sheet 1



Inventor:
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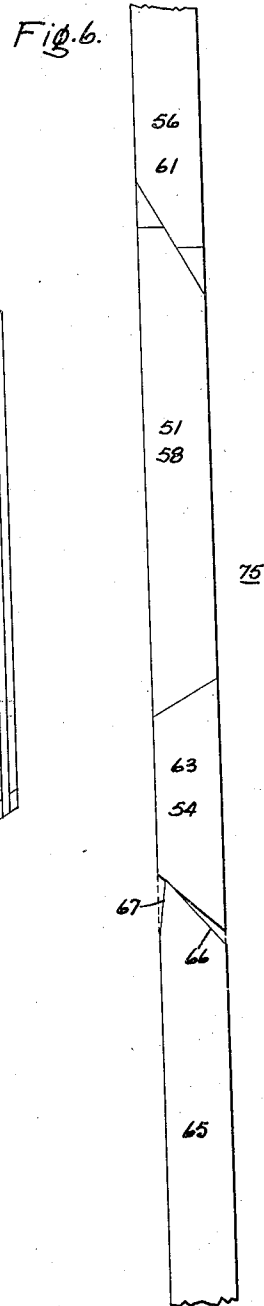
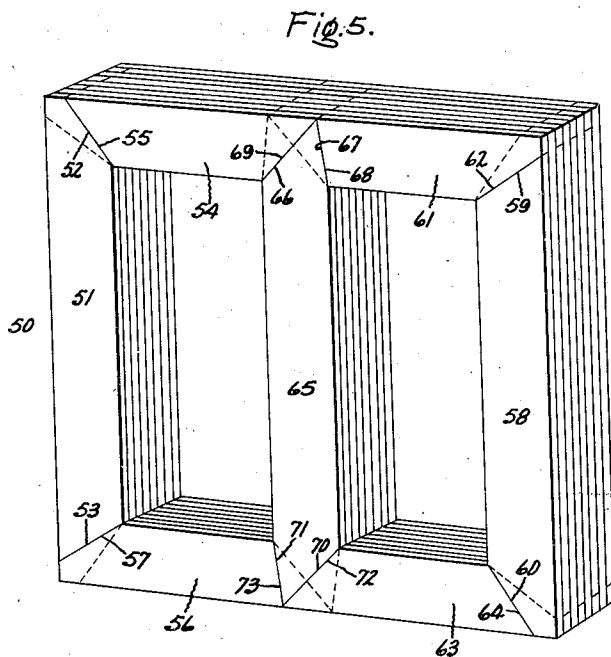
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MAGNETIC CORE

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,407,688

MAGNETIC CORE

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Application December 30, 1942, Serial No. 470,579

7 Claims. (Cl. 175—356)

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My invention relates to laminated magnetic core structures for electrical induction apparatus such as transformers and reactors.

In the usual construction of magnetic cores, the laminations are cut or punched from relatively large stock sheets which are produced by rolling from bars or billets of a suitable magnetic material, such as various steel alloys, such as silicon steel or a magnetic nickel iron steel. It is known that the rolling process produces a grain structure in sheets which may extend in the direction in which the sheets have been rolled. It is further known that the path of least magnetic resistance of such material is generally in the direction that the sheets have been rolled, though in certain types of steels the most favorable magnetic direction, in so far as low flux losses are concerned, may be at some angle with respect to the direction of rolling. Thus, it will be seen that for optimum results for magnetic cores it is desirable to cut the laminations from sheets of magnetic material so that the core flux path is parallel with the path of least magnetic resistance, or parallel with the direction of rolling even at the corners.

One common form of magnetic core consists of a stack of L shaped punchings, but it will be apparent that such shapes cannot be punched as a single piece from a standard stock in such a manner that the most favorable magnetic direction extends parallel with the flux path in both parts of the punchings. This is due to the fact that the grain extends in the same direction throughout all parts of the stock while the two parts of the L shaped punchings are at right angles to each other. Another common form of a core consists of a rectangular core with adjacent laminations being stacked at right angles with respect to each other. While the most favorable magnetic direction of this type of core may be made parallel with the direction of the flux path throughout the central portion of the laminations, the core flux must be cut crosswise of the most favorable direction at the ends of the laminations in traversing from one core leg to the next. Due to this crosswise flow of flux at the corners of the core, relatively high losses occur at these points.

One way of overcoming the difficulties referred to above is to provide a core structure by winding a ribbon of suitable magnetic steel so that there will be no joints and so that all the flux will pass parallel to the direction of rolling of the material or in the direction which has the least magnetic reluctance. Such a type of wound core has

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been found to be very successful in the production of relatively small size transformers, which are called distribution transformers in the trade. Due to the various mechanical difficulties, however, it has been less economical to wind much larger sizes of ribbon sheet material so as to produce sufficiently large cores for electrical apparatus having a high kva. capacity.

Another way of providing cores of laminated material in which the direction of flux path is along the line of least magnetic reluctance in the vicinity of the joints is to assemble the laminations, each corner of which has been cut on the diagonal, so as to provide a mitered joint at each of the corners. It will be seen, however, that when each of the joints at the various corners of the rectangular core are coincident with the diagonal running from the inside corner to the outside corner all of the joints will be in substantial registry so that the possibility of gaps being formed at the joints for increasing the magnetic reluctance is appreciable, even though elaborate means are provided for clamping the magnetic laminations together.

An improved arrangement for providing mitered joints at the various corners of the assembled laminations and for preventing separation at the joints is described and claimed in patent application S. N. 376,304, Granfield, filed January 28, 1941 (now Patent 2,348,003 dated May 2, 1942), and assigned to the same assignee as this present invention. In that application there is described a stacked laminated core formed of laminations which have mitered butt joints with extensions and corresponding indentations in the edges of the adjacent laminations, so as to prevent an appreciable gap from being formed at the butt joint. The various layers which are stacked to form the core are made up of similarly assembled laminations which are oppositely arranged so as to stagger the adjacent joints of contiguous layers. In this manner there will be a minimum of magnetic flux which will pass crosswise of the most favorable magnetic direction and due to the projections and corresponding interfitting indentations which may extend in opposite directions for the adjacent joints of contiguous layers an overlapping will be provided at the joints so as to substantially preclude separation of the laminations of the assembled core.

There is also described in an application S. N. 470,578 to Brand, filed concurrently herewith, and assigned to the same assignee as this present invention, a corner construction which provides a minimum of magnetic reluctance at the corners

and which also provides overlap so as to minimize separation of the stacks of the assembled core. In the construction of this application mitered butt joints are provided at the corners of each layer of laminations, the joints between laminations of one layer being displaced or offset from the adjacent joints of a contiguous layer. The offsetting is obtained by cutting one edge of each of the laminations on a diagonal so that the joints will be coincident with the diagonal running from the inside to the outside corner of the assembled laminations and cutting the other ends of the laminations with a mitered butt joint which is offset or displaced from a diagonal running from the inside corner to the outside corner of the assembled laminations. These latter joints are obtained by notching the corner or providing a first portion which is parallel with a longitudinal axis of the assembled core and a second portion of a corner which is parallel with the diagonal. The laminations are then stacked to provide layers, and the layers are oppositely arranged so that the joints between laminations of one layer will be offset from joints between laminations of a contiguous layer. Thus, a joint between laminations of one layer which is coincident with the diagonal will be adjacent to but staggered from a joint of the adjacent or contiguous layer which is offset from the diagonal.

In application S. N. 470,580 Welch, filed concurrently herewith and assigned to the same assignee as the present invention there is described an improved magnetic core in which each of the corner joints are mitered and the adjacent joints between laminations of contiguous layers are offset on opposite sides of a diagonal running from the inside corner to the outside corner of the assembled laminations. In this manner with such a construction a minimum of flux path is provided which is at an angle to the most favorable magnetic flux direction. This construction is obtained by notching the joints with the broken line joints having a small portion of the joints parallel with the longitudinal axis of the assembled laminations and the adjacent joints between laminations of a contiguous layer has a small portion which is parallel with the lateral axis of the assembled laminated core.

It is, therefore, an object of my invention to provide a laminated core of the types described above with an improved construction which will have a relatively small resistance to the flow of flux at the corners of the assembled lamination, and which will have a corner shaped so as to facilitate assembly of the laminations.

Another object of my invention is to provide a new and improved core construction in which the laminations are so cut from metal stock that when fitted together into a unit, the core flux may flow in the most favorable magnetic direction of the laminations throughout a large portion of the magnetic circuit.

A further object of my invention is to provide a core construction having separate laminations with a corner construction such as to facilitate the manufacture thereof as well as to provide an efficient assembled core construction.

A further object of my invention is to provide an improved corner construction for a laminated magnetic core so that the reluctance of the joint varies in a direction and to an extent to make a substantial reduction in inequality of total magnetic reluctance along the loops of different lengths of magnetic flux paths of the core.

Further objects and advantages of my inven-

tion will become apparent from the following description referring to the accompanying drawings, 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 drawings Fig. 1 is an exploded perspective view of layers of assembled laminations, the laminations being formed in accordance with an embodiment of my invention; Figs. 2 and 3 illustrate curves which will be employed in the description of my invention; Fig. 4 illustrates a method of stamping the laminations employed in the construction of Fig. 1 from ribbon of magnetic material with a minimum of waste; Fig. 5 is a perspective view of a three-legged core which is provided with an embodiment of my invention, and Fig. 6 illustrates a method whereby the laminations employed in Fig. 5 may be cut from a ribbon of steel with a minimum of waste.

Referring to Fig. 1 of the drawings I have illustrated a magnetic core having a plurality of layers of stacked laminations. Any suitable number of layers may be used depending upon the size of the core which is desired. Each of the layers includes a plurality of separate laminations which are closely fitted at their ends forming butt joints. Any suitable number of laminations may be employed to form each of the layers, and in the construction illustrated in Fig. 1, four such laminations are employed to form a single layer of what may be called a single phase core for a suitable electric induction apparatus, such as a transformer.

It is to be understood, however, that a core having any suitable number of legs and yokes may be formed according to my invention. Thus, in Fig. 1 I have illustrated a layer 10 including laminations 11 and 12 which may be called leg sheets and laminations 13 and 14 which may be termed yoke sheets. It is to be understood, however, that the leg sheets 11 and 12 could be yoke sheets and the yoke sheets 13 and 14 could be the leg sheets, if desired. The various laminations may be formed from strip material having the most favorable magnetic direction lengthwise of the strip so as to provide a core with a minimum magnetic reluctance. These laminations could be punched with a 45 degree angle at the ends and thus attempt to provide substantially no path in the corners through which the flux must pass crosswise of the most favorable direction. However, as has been stated above, if all the joints are in substantial registry there is considerable difficulty in preventing gaps from being formed at the butt joints, even though elaborate clamping arrangements are provided. In order, therefore, to provide an assembled laminated structure which not only has a minimum reluctance at the corners, but which also is formed so as to provide overlapping between adjacent laminations of contiguous layers so as to maintain the tightness of the joints throughout normal use of the device, I provide corner constructions which not only have a substantially mitered or diagonally extending butt joint but the edges of the laminations which form the joints are so cut and so assembled as to be displaced or offset from the adjacent joints of the contiguous layer of laminations and thereby provide overlapping. Thus, the lamination 11 is formed with an end 15 which is cut at an angle of less than 45 degrees with an axis of the assembled laminations. In Fig. 1 it will be seen that I have shown the edge 15 which is cut at an angle of substan-

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tially 30 degrees with the longitudinal axis of the assembled laminations. The other end of the lamination 11 has an end 16, the surface of which makes an angle of less than 45 degrees with the lateral axis of the assembled laminations. Thus, as will be seen in Fig. 1 the end 16 makes an angle of approximately 30 degrees with this lateral axis. In order to provide a relatively tight butt joint between the edge 16 and an adjacent edge 17 of the lamination 13, it will be seen that the edge 17 is also cut at an angle which is less than 45 degrees with the lateral axis, or 30 degrees as is illustrated in Fig. 1. The opposite end of the lamination 13 has an edge surface 18 which is cut at an angle less than 45 degrees with the longitudinal axis and in Fig. 1 it will be seen that the angle is about 30 degrees. It will also be seen that the lamination 12 is similar to the lamination 11, it only being oppositely disposed in assembled condition with respect to the lamination 11. Thus the lamination 12 has an edge surface 19 which abuts against the adjacent surface 18, the surface 19 making a similar angle of 30 degrees with a longitudinal axis while the opposite edge surface 20 of the lamination 12 makes an angle of 30 degrees with the lateral axis of the assembled lamination. Furthermore, the lamination 14 is similar to the lamination 13 except being oppositely arranged in an assembled condition. Thus, the lamination 14 has an edge surface 21 which abuts against the surface 20 and is therefore at an angle of 30 degrees with a lateral axis while the opposite edge surface 22 of the lamination 14 abuts against the surface 15 of the lamination 11 and, therefore, makes an angle of 30 degrees with a longitudinal axis.

Since the layer of lamination 10 has butt joints all of which are offset on one side of diagonals running from the inside corners to the outside corners of the assembled laminations at the various corners as is shown in Fig. 1, by forming an adjacent layer 25 of laminations similar to those employed to form the layer 10 and then stacking the layers so that the layer 25 is reversed or oppositely arranged with respect to the layer 10, the joints at each of the corners will be offset from each other so as to provide overlapping at the various laminations of each layer with the adjacent laminations of a contiguous layer in the vicinity of the joint. Thus adjacent laminations have diagonal butt joints at adjacent ends with at least a major portion thereof being a straight line and running from the vicinity of the inner corner to the vicinity of the outer corner of the assembled laminations. With this construction it will be seen that the slight overlapping will accomplish the mechanical results of substantially preventing separation of the laminations and thereby minimize the possibility of gaps being formed at the butt edge. It will also be seen that the joints between adjacent laminations of contiguous layers are not only oppositely but symmetrically disposed on either side of the diagonal running from the inside corner to the outside corner of the assembled laminations. Thus adjacent butt joints of two superimposed layers form an acute angle with each other to provide overlapping which tapers in a direction crosswise of the laminations and toward the shorter perimeter of the core.

Although the lamination layers in Fig. 1 are shown with each contiguous layer being oppositely arranged with respect to the adjacent layer, it is to be understood that any suitable number of layers, if desired, may be stacked so that the

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joints are in registry and then stack another suitable number which are oppositely disposed with respect to the first group. In any case there will always be two contiguous layers which are oppositely arranged so as to provide an offset at the joints between these layers.

It will be seen that with a plurality of layers of laminations formed in the manner described above a relatively small amount of flux at the edges will pass crosswise of the grain, and with such a construction considerable improvement in efficiency is obtained over that in which the laminations are formed with overlapping rectangular joints. This is illustrated in Fig. 2 in which the curve 35 illustrates the per cent loss in the core joints of the conventional joints having rectangular overlappings while the curve 36 illustrates the loss in the core joints with joints made according to my invention. In Fig. 2 the per cent core loss is plotted as abscissa and the per cent flux density is plotted on the ordinate axis. In order to further show the improvement in operation of cores formed according to my invention over those formed with rectangular shaped laminations I have illustrated in Fig. 3 the characteristics in which the per cent exciting current is plotted as abscissa and per cent density plotted as ordinate. Curve 37 illustrates the characteristics of a conventional core having rectangular ends while curve 38 represents the characteristics of a core formed with my improved joint construction.

A further advantage of tapering the joints of the corners in the manner described above is that the overlap is wider at the longer perimeter of the core and narrower at the shorter so that the joint reluctance of the core is a little less at its longer perimeter and therefore tends to compensate for the greater reluctance of the iron portion of the magnetic circuit along the longer perimeter, thus helping to equalize the total reluctance along each perimeter and thereby equalize the distribution of the flux, as the flux otherwise tends to crowd to the shorter perimeter of the core. A further advantage of my improved construction is that the joint has greater friction and stability due to its relatively wider overlap near the outside perimeter.

Not only is a core formed with my improved laminations efficient in operation but the laminations may be formed from a constant sheet material with a relatively small amount of waste. I have thus illustrated in Fig. 4 a strip of magnetic material 40 having the most favorable direction of flux parallel with the axis as shown by the arrow. The various laminations may then be punched from this strip of magnetic material 40 with only two different dies and with a relatively small waste at every other cut. Thus in Fig. 4 I have illustrated the cutting of the lamination 12 with the edge 19. It will be seen that for instance the lamination 13 has an edge 17 which may be cut along the edge which forms the edge 19, and the only waste will be relatively small rectangular portions 41 and 42. However, the opposite edge 18 of the lamination 13 has such a configuration that it is similar to an edge 16 of the lamination 11. Thus no waste will result when making the cut to form the edges of half the laminations.

In view of the above it will be seen that I have provided an improved core construction formed of layers of laminations in which not only does the maximum of flux pass in the direction of most favorable magnetic conductance but over-

lapping is provided at the ends so as to preclude separation at the butt joint. Furthermore the various layers may be formed of a similar width or of an equal width and be punched from the same strip with only a relatively small amount of waste at every other punch. Furthermore, with my construction the corners are so formed as to provide no voids at the assembled corners of the laminated core.

It is to be understood that my invention may be applied to a core having any suitable number of laminations per layer and in Fig. 5 I have illustrated my invention as applied to a three-legged core which may have application to a three-phase core including a plurality of layers each having seven assembled laminations. In the arrangement illustrated in Fig. 5 it will be seen that the various layers are made of similar laminations except that the laminations are stacked in reverse order in adjacent laminations to provide overlapping at the joints. The layer of laminations 50 includes an outer leg sheet 51 which has an edge 52 making an angle less than 45 degrees with the longitudinal axis which, in the illustrated embodiment of my invention, is 30 degrees, and an opposite edge 53 which makes an angle less than 45 degrees or 30 degrees with the lateral axis of the assembled laminations. Cooperating with the leg sheet 51 is provided a yoke sheet 54 having an edge 55 which abuts the edge 52 and a yoke sheet 56 having an edge 57 which abuts the edge 53 of the lamination 51. Another outer leg sheet 58 is provided having ends similar to the leg sheet 51, the leg sheet 58 being oppositely arranged in the layer 50. Thus, the leg sheet 58 has an edge 59 which makes an angle less than 45 degrees with the lateral axis or 30 degrees and an edge 60 which makes an angle of less than 45 degrees or 30 degrees with the longitudinal axis of the assembled laminations. Cooperating with the leg sheet 58 there is provided a yoke sheet 61 having an edge 62 which abuts the edge 59 and another yoke sheet 63 having an edge 64 which abuts the edge 60 of the lamination 58. A center leg 65 is provided having an edge 66 which makes an angle greater than 45 degrees or about 50 degrees with the lateral axis of the assembled laminations so that the leg sheet 65 may be punched from a strip of material having a width similar to that of all the laminations and still be able to provide an edge 67 which is on a slight diagonal. An edge 68 is provided on the yoke sheet 61 for cooperating with the edge 67 of the center leg sheet 65. Also, an edge 69 is provided on the yoke sheet 54 for abutting the edge 66 of the center leg 65. The opposite end of the leg sheet 65 has a similar edge which is opposite to the upper end and includes an edge 70 which makes an angle greater than 45 degrees with the lateral axis of the assembled laminations so as to provide a diagonal edge 71 even though the width of the leg sheet 65 is similar to the width of the remaining laminations. The yoke sheet 63 is also provided with a cut edge 72 which abuts the edge 70 and the yoke sheet 56 is provided with an edge 73 which abuts the edge 71 of the center leg sheet 65.

In Fig. 6 I have illustrated how the seven laminations may be cut from a ribbon of steel 75 with a minimum of waste. In Fig. 6 I have numbered the cut laminations similar to the numbers in Fig. 5 and it will be seen that the yoke sheets 56 and 61 are similar, the leg sheets 51 and 58 are similar, and the yoke sheets 54 and 63 are similar. Thus a small amount of waste will be

formed when cutting the edges between the yoke sheet 56 and the leg sheet 51 and a small amount of waste will be formed when cutting the edge between the yoke sheet 54 and the leg sheet 65. However, the various laminations may be cut from a ribbon of steel with a relatively small amount of waste.

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. A magnetic core including a plurality of layers of assembled laminations formed lengthwise from strip material having the most favorable magnetic direction lengthwise of the strip, adjacent laminations having a diagonal butt joint at adjacent ends, with at least a major portion thereof being a straight line and running from the vicinity of the inner corner to the vicinity of the outer corner of the assembled laminations, each of said laminations having a first joint edge surface at an angle of less than 45 degrees with a lateral axis of the assembled laminations and a second joint edge surface at the opposite end at an angle of less than 45 degrees with the longitudinal axis of the assembled laminations.
2. A magnetic core including a plurality of layers of assembled laminations formed lengthwise from strip material having the most favorable magnetic direction lengthwise of the strip, adjacent laminations having a diagonal butt joint at adjacent ends with at least a major portion thereof being a straight line and running from the vicinity of the inner corner to the vicinity of the outer corner of the assembled laminations, each of said laminations having a first joint edge surface at an angle of less than 45 degrees with a lateral axis of the assembled laminations and a second joint edge surface at the opposite end at an angle of less than 45 degrees with the longitudinal axis of the assembled laminations, said laminations of each layer being assembled with a first joint edge surface of one lamination fitting a second joint edge surface of the adjacent lamination.
3. A magnetic core including a plurality of layers of assembled laminations formed lengthwise from strip material having the most favorable magnetic direction lengthwise of the strip, adjacent laminations having a diagonal butt joint at adjacent ends with at least a major portion thereof being a straight line and running from the vicinity of the inner corner to the vicinity of the outer corner of the assembled laminations, each of said laminations having a first joint edge surface at an angle of less than 45 degrees with a lateral axis of the assembled laminations and a second joint edge surface at the opposite end at an angle of less than 45 degrees with the longitudinal axis of the assembled laminations, said laminations of each layer being assembled with a first joint edge surface of one lamination fitting a second joint edge surface of the adjacent laminations, contiguous layers of said assembled laminations being oppositely disposed so as to provide overlapping of adjacent laminations of contiguous layers.
4. A magnetic core including a plurality of layers of assembled laminations formed lengthwise from strip material having the most favorable magnetic direction lengthwise of the strip, ad-

jacent laminations having a diagonal butt joint at adjacent ends with at least a major portion thereof being a straight line and running from the vicinity of the inner corner to the vicinity of the outer corner of the assembled laminations, each of said laminations having a first joint edge surface at an angle of about 30 degrees with a lateral axis of the assembled laminations and a second joint edge surface at the opposite end at an angle of about 30 degrees with the longitudinal axis of the assembled laminations.

5. A magnetic core including at least two superimposed layers of laminations, each layer including a substantially straight line butt joint in its magnetic circuit running from the vicinity of the inner corner of the assembled laminations, and the butt joints of said two layers forming an acute angle with each other whereby a lamination of one layer overlaps the joint of the other layer, said overlap between said two joints being tapered in a direction crosswise of said laminations.

6. A magnetic core including at least two super-

imposed layers of laminations, each layer including a substantially straight line butt joint in its magnetic circuit running from the vicinity of the inner corner of the assembled laminations, and the butt joints of said two layers forming an acute angle with each other whereby a lamination of one layer overlaps the joint of the other layer, said overlap between said two joints being tapered in a direction crosswise of said laminations and tapered towards the shorter perimeter of said core.

7. A magnetic core containing at least two straight portions meeting at an angle and forming a corner, and including at least two layers of laminations, each layer including a generally-diagonal continuously straight line butt joint extending from the vicinity of the inner corner to the vicinity of the outer corner of the assembled straight portions, one of said joints terminating on one side of said outer corner and the other joint terminating approximately the same distance on the other side of said outer corner.

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