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2,960,756

METHOD OF MAKING MAGNETIC CORES

Filed Nov. 16, 1953

2 Sheets-Sheet 1

Fig. 1.

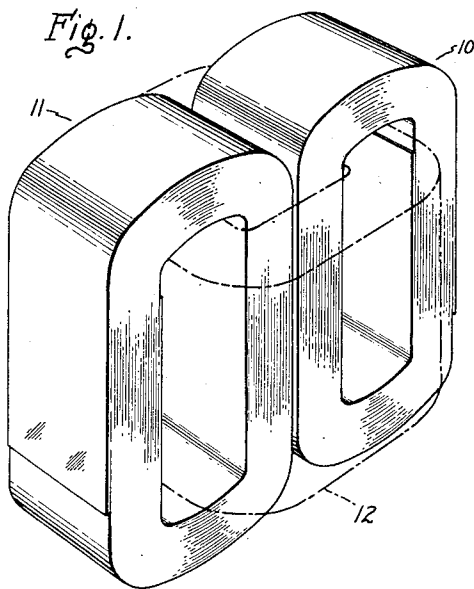
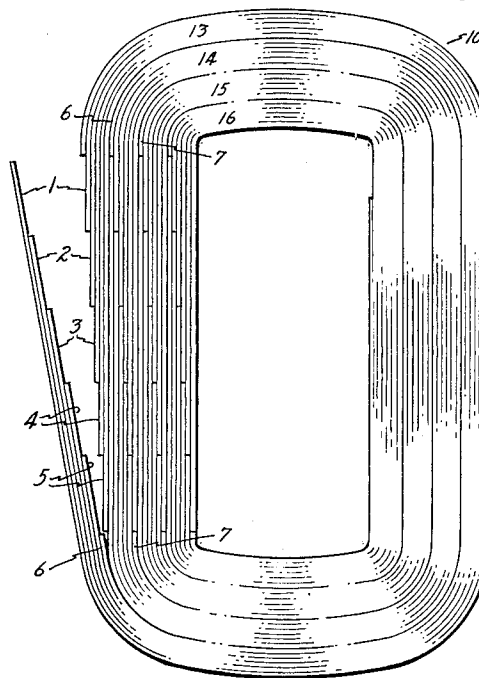


Fig. 2.

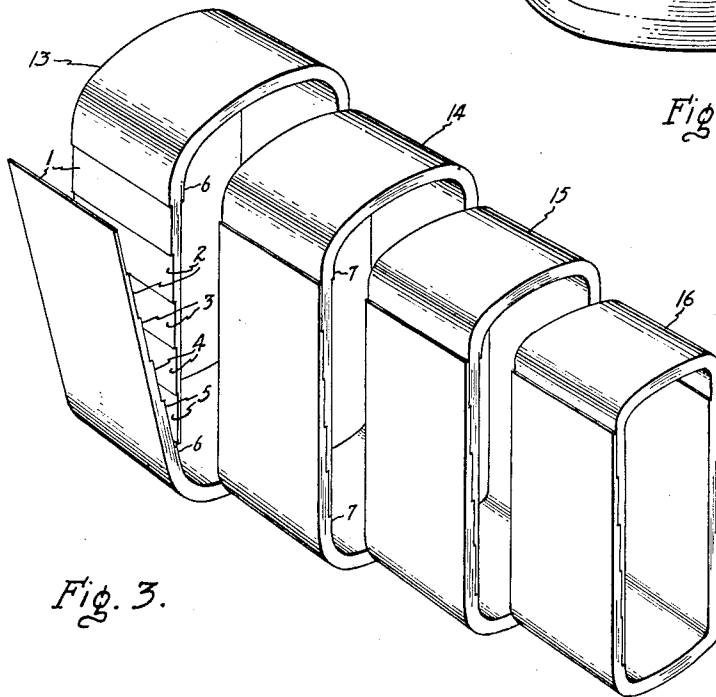


Fig. 3.

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Fig. 4.

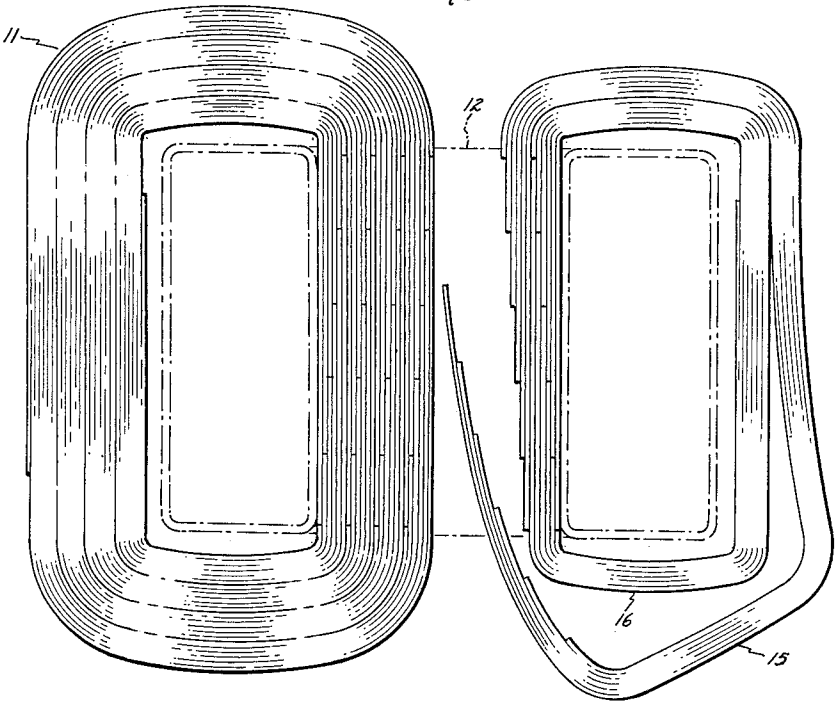


Fig. 6.

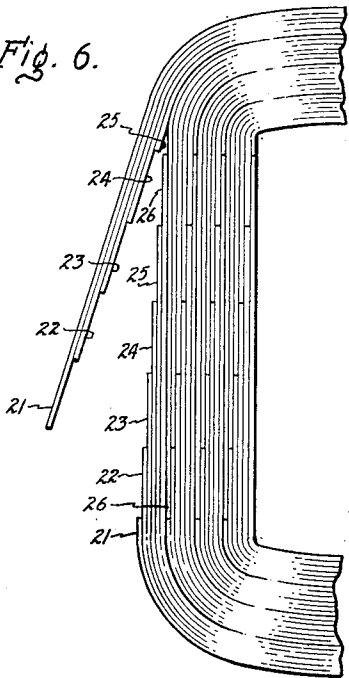


Fig. 5.

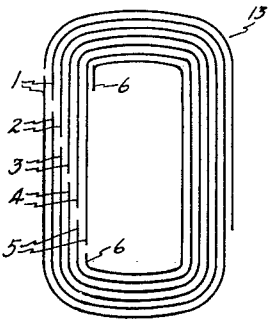
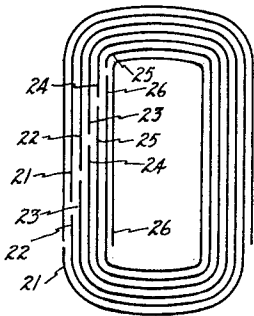


Fig. 7.



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METHOD OF MAKING MAGNETIC CORES

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4 Claims. (Cl. 29—155.58)

This invention relates to a magnetic core, and more particularly, to a wound magnetic core and a method of forming and assembling same.

It is well known practice in the stationary electrical induction apparatus art to continuously wind a strip of magnetic core material into a closed circular-like core section having a plurality of turns. After the winding operation, a forming operation follows in order to obtain a neatly and tightly assembled annular or rectangular-like core section. However, the forming operation can be omitted by directly winding the strip of material into an annular or rectangular-like form. In such a core section, the strip of magnetic core material can be a flat metallic strip having its grains oriented in the lengthwise direction of the strip to obtain minimum core losses. During said winding and forming operations, strains are set up in said strip due to repeated flexing of said strip. Accordingly, after the winding and forming operations said core section is annealed to remove said strains. Following the annealing operation a butt joint cut is made transverse to a portion of the core section through all the core section turns so that the core section can be hinged or sprung open for assembly about a preformed coil assembly having a window opening therein.

The above described procedure has several disadvantages. With all the cuts of each turn aligned in substantially one common plane, the disturbance of magnetic flux around the cut in one turn affect the disturbance of flux around the cuts in the adjacent turns thereby increasing the core losses and greatly increasing the exciting current. Also, with a single butt joint cut made in the core section difficulty is encountered in accurately closing said butt joint cut after hinged opening of the core section. Furthermore, inasmuch as the core section has a great number of turns or laminations, forces of rather large magnitude must be applied to hinge the core section open and said butt joint cut must be opened up for a considerable distance to enable the core section to be slipped into the coil assembly. Thus, besides the hinged opening operation being rather difficult, the core section may be flexed to such a degree as to set up permanent deformations therein, still further increasing the core losses.

Accordingly, it is an object of this invention to provide a method of making a magnetic core section that can be readily hinged opened and accurately closed whereby said core section will have a minimum of core losses and exciting current.

It is a further object of this invention to provide a method of forming and assembling a magnetic core section whereby minimum losses are introduced into said core section.

My invention comprises a closed spirally wound strip core section having a plurality of turns therein, a plurality of series of cuts in said turns whereby said turns have a length equal to approximately one complete turn of said core section, each series of cuts commencing adjacent one end of one side of said core section and ending

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adjacent another end of said one side. The magnetic core of my invention is claimed in my copending divisional application Serial Number 712,135, filed January 30, 1958, and assigned to the same assignee as the instant application.

My invention further comprises a method of forming and assembling a closed core section about a preformed electrical winding coil assembly comprising winding a strip of magnetic material into a closed core section, unwinding said strip of material and cutting said strip into a plurality of series of turn elements having a length equal to approximately one complete turn of said core section, a first series of turn elements formed by making a cut in said strip adjacent one end of one side of said closed core section and successively cutting said strip at points along said one side progressively closer to the other end of said one side until said other end is reached, assembling said first series of turn elements into a closed packet, subsequent series of turn elements formed by making another first cut in the remainder of said strip adjacent said one side one end and successively cutting said strip remainder at points along said one side progressively closer to said one side other end until said other end is reached, assembling each of said subsequent series into individual closed packets, then opening said packets and assembling them in the inverse order from which they were formed about said preformed coil assembly.

The invention will be better understood by considering the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the drawings, Fig. 1 is a view in perspective, of one form of electrical induction apparatus in which the invention may be used. Fig. 2 is a front view of the right-hand core section of Fig. 1, illustrating how said core section is unwound and cut into a plurality of packets. Fig. 3 is an exploded perspective view of the packets formed from the core section shown in Fig. 2. Fig. 4 is a front view of the form of invention disclosed in Fig. 1 illustrating how the packets of Fig. 3 are assembled to form the right-hand core section of Fig. 1. Fig. 5 is a diagrammatic showing of the cutting operation employed in Fig. 2 to better illustrate said cutting operation. Fig. 6 is a front view, partly broken away, of a core section embodying another form of my invention. Fig. 7 is a diagrammatic showing of the cutting operation employed in the Fig. 6 form of invention. Like reference numerals throughout the various figures are used to designate identical parts.

Referring now to the drawings, and more particularly to Fig. 1, shown therein is a stationary electrical induction apparatus or transformer comprising two annular or rectangular-like core sections 10 and 11 linked with a preformed annular or rectangular-like electrical winding coil assembly 12. Each of the core sections 10 and 11 and the winding assembly 12 have a window opening therein whereby the core sections 10 and 11 can be looped through the window opening of the winding assembly 12 in a manner well known in the art. The core sections 10 and 11 are identically constructed and the manner of forming and assembling the core sections 10 and 11 is illustrated in Figs. 2, 3, 4 and 5.

The core section 10, for instance, is formed by continuously spirally winding a flat strip of magnetic material about a mandrel or the like into a plurality of concentric turn laminations. As will be obvious to those skilled in the art, during said winding operation suitable spacing material, not shown, is inserted between adjacent turns of the strip to facilitate reassembly of the core section 10 after the strip has been unwound and cut. If the strip is not directly wound into an annular or rec-

tangular-like form, but into a circular-like core section, the wound core section undergoes a forming operation whereby the turn laminations of the core section will be neatly and tightly arranged with respect to each other to present a closed annular or rectangular-like core section. During said winding and forming operations mechanical strains are set up in the strip of magnetic material due to repeated flexing of said strip of material. Therefore, after said winding and forming operations the core section is placed in an oven or the like for a heat treating or annealing operation whereby said mechanical strains are relieved. The winding, forming, and annealing operations just described are well known in the art.

After the annealing or heat treating operation, the continuously wound strip of magnetic material is unwound from the annealed core section and cut into a plurality of turns having a length of approximately one complete turn of said core section. A plurality of individual packets are assembled from said cut turns and said packets are then assembled about the preformed winding assembly 12 in the inverse order from which they were formed as will be more clear hereinafter.

The unwinding and cutting operation is disclosed in Figs. 2 and 5. As seen in Fig. 2, a cut is made in the outermost turn of the continuous strip of magnetic material adjacent the upper left-hand side portion of the core section 10. The outermost turn or lamination 1 is then unwound and another cut is made in the continuous strip of magnetic material at a point along the left-hand side of core section 10 offset or staggered with respect to the first cut towards the lower end of the left-hand side portion of core section 10. After the outer turn or lamination 1 is removed the second turn or lamination 2 of the continuous strip of magnetic material is unwound and then cut at a point along the left-hand side portion of core section 10 offset or staggered with respect to the second cut towards the lower end of the left-hand side portion of core section 10. The unwinding and cutting operation just described is repeated until a plurality of turn laminations having a length of approximately one complete turn of the core section 10 are obtained. Each subsequent cut in the strip of material is made at a point progressively closer to the lower end of the left-hand side portion of core section 10 whereby the last cut of a first series of cuts is made at a point disposed at the lower end of the left-hand side portion of core section 10. Said last cut of the series of cuts defines the terminating end of turn lamination 5 and the commencing end of turn lamination 6. The cut turn laminations 1, 2, 3, 4 and 5 are assembled as they are being cut and unwound into a packet 13 shown in Fig. 3.

The turn laminations comprising packet 13 and the manner of making the first series of cuts in the continuous strip of magnetic material to obtain packet 13 possibly is more clearly illustrated in Fig. 5. As illustrated in Fig. 5, the just described unwinding and cutting operation enables all the cut turns or laminations to be easily reassembled with respect to each other in the same position they occupied before they were unwound and cut. That is, the commencing end of each cut turn lies in the same plane as the terminating end of an immediately preceding cut turn. For instance, the terminating end of turn or lamination 1 is positioned radially inward of the commencing end of turn or lamination 1 and is staggered with respect thereto towards the lower end of the left-hand side of the core section whereby it lies in the same plane as the commencing end of turn 2. The terminating ends of the other turns or laminations are similarly arranged with respect to their commencing ends whereby each cut turn or lamination has a length slightly greater than one complete turn of the core section.

Referring again to Fig. 2, after the outermost series of turns 1 to 5 are formed and assembled into packet 13 shown in Fig. 3, the remainder of the continuous strip of magnetic material is unwound for approximately three-

quarters of a complete turn of the closed core section and is again cut at the upper end of the left-hand side portion of core section 10 to commence another series of cuts which will progressively be spaced closer to the lower end of the left-hand side portion of core section 10. After another five turns of the continuous strip of material are unwound and cut another packet 14 shown in Fig. 3 is formed out of the second series of cut turns or laminations. The three-quarters of a turn lamination 6 is assembled with packet 13. However, turn 6 can also be assembled with packet 14 if so desired. The last cut of the second series of cuts will be made at the lower end of the left-hand side portion of core section 10. The first cut of the third series of cuts will be made at the upper end of the left-hand side portion of core section 10. Accordingly, the last cut of the second series of cuts and the first cut of the third series of cuts will define another three-quarters turn 7. Three-quarters turn 7 is assembled with the second packet 14 but can be assembled with packet 15 formed subsequent thereto. The unwinding or cutting operation as above described is repeated until a plurality of packets 13, 14, 15 and 16 are obtained.

Thus, it will now be seen that the unwinding and cutting operation comprises unwinding the continuous strip of material from the annealed core section one turn at a time and cutting said strip into lengths slightly greater than one complete turn of the core section except for the transitional pieces between the packets which have a length of approximately three-quarters of a turn. A plurality of series of cuts are made in said core section and each first cut of each of said plurality of series is made at a same end of a same side of the annular or rectangular-like core section. Each subsequent cut of the series of cuts is positioned radially inward of the immediately preceding cut and is staggered with respect thereto towards the other end of said same side of the core section whereby the last cut of each series of cuts will be disposed at a point adjacent said other end of said same side.

The number of packets, the number of turns in each packet, and the spacing between the cuts will have been previously determined with several factors in mind. The cuts should be far enough apart to avoid the disturbance of flux around one cut from affecting the disturbance of flux around the cut in the next adjacent turn. Also, the resulting packets should be of such thickness and flexibility as to be capable of being sprung around the preformed winding coil assembly 12 without permanent deformation of the turns comprising the completed core section 10. Many strip wound magnetic cores are made out of flat magnetic strip material having a 12 mils thickness. For such a thickness it is suitable that the cuts be spaced from each other by $\frac{3}{16}$ to $\frac{1}{16}$ of an inch to avoid the disturbance of flux around one cut from affecting the disturbance of flux around the cut in the next adjacent turn.

After the continuously wound annealed core section is cut into the packets 13, 14, 15 and 16, said packets are assembled about the preformed winding coil assembly 12 as shown in Fig. 4. The smallest or innermost packet 16 is opened up and sprung around the coil assembly 12 with the joints or cuts of the packet 16 positioned within the window opening of the coil assembly 12 as shown in Fig. 4. With properly proportioned packets, the packets may be hinged or sprung open and looped about the windings 12 without exceeding the elastic limit of the strip material and thus affecting the magnetic properties of the magnetic strip material. The next larger packet 15 is similarly hinged opened and sprung about the windings 12 in superposed concentric relationship with the smallest packet 16. This procedure is repeated until all of the packets are sprung about the coil assembly 12 and disposed with respect to each other in a concentric relationship to form a closed magnetic core section. The turns of the completely assembled core section and the packets thereof may be secured together by applying a cement

along the cut faces of the turns or between the packets or the core turns may be secured together by clamps alone. The cuts of the completed core section preferably are disposed within the window opening of the electrical windings 12 inasmuch as with such an arrangement the packets comprising the completed core section need be hinged open only a minimum amount for springing about the electrical windings 12.

In the core section 10 shown in Fig. 2 the strip of material comprising the core section was initially wound clockwise in a spiral from its radially inner end outwardly towards its radially outer end. It should be noted that if the continuous strip of material was initially wound counterclockwise into a closed core section the first cut of each series of cuts would have been made at the lower end of the left-hand side portion of core section 10 in order to secure cut turns of slightly more than one complete turn length with the cuts progressing towards the upper end of the left-hand side of core section 10 whereby the last cut of each series of cuts would have been disposed at the upper end of the left-hand side portion of core section 10. This will be readily apparent by viewing the core section 10 of Fig. 4 when Fig. 4 is inverted.

Referring now to Figs. 6 and 7, shown therein is another form of my invention wherein the cut turns of the core section extend for a length slightly less than one complete turn of the core section. In this form of my invention each series of cuts is commenced at the lower end of the left-hand side portion of the core section and the series of cuts progresses towards the upper end of the left-hand side portion of the core section until the last cut of each series is positioned at the upper end of the left-hand side portion of the core section. Thus, viewing Figs. 6 and 7 together, it will be seen that a first cut is made in the outer turn or lamination of a continuously clockwise wound strip material core section adjacent the lower left-hand corner thereof. The first lamination 21 is unwound and then a second cut is made in the strip of material at a point radially inward of the first cut staggered or offset with respect thereto towards the upper left-hand corner of the core section. The first and second cuts define the first turn or lamination 21. The second turn or lamination 22 is unwound and a third cut is made radially inward of the second cut staggered and offset with respect thereto towards the upper end of the left-hand side portion of the core section. The strip of material defined by the second and third cuts constitutes the second turn or lamination 22 of the first packet of turns or laminations. This cutting and winding operation is continued until five turns or laminations 21 to 25 are obtained. Said turns or laminations 21 to 25 are stacked in a packet. The last cut of the first series of cuts is disposed adjacent the upper left-hand corner of the core section and defines the terminating end of lamination 25 and the commencing end of lamination 26. The transitional lamination 26 is unwound for approximately one and one-quarter turns of the core section and is then cut adjacent the lower left-hand end of the core section similar to the first cut of the first series of cuts. Turn or lamination 26 can be stacked with the first packet of turns or laminations or with the second packet of turns or laminations. The unwinding and cutting operation just described is repeatedly periodically until a plurality of packets are obtained. Then, as in the first form of invention the packets are assembled in the inverse order from which they were formed about a preformed electrical winding coil assembly.

In the Figs. 6 and 7 form of invention, the series of cuts were always commenced at the lower left-hand corner of the core section in order to obtain cut turn laminations having a length of slightly less than one complete turn of the core section inasmuch as the strip of material was initially wound clockwise into a closed core section. However, it should be noted that if the strip of magnetic material continuously wound into a closed core section had been spirally wound counterclockwise and radially

outward to obtain cut turn laminations having a length slightly less than one complete turn of the core section the series of cuts would have been commenced adjacent the upper left-hand corner of the core section.

While there have been shown and described particular embodiments of the invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention, and that it is intended by 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 method of forming and assembling a core section with an electrical winding assembly having a window opening therein, said method comprising spirally winding a continuous flat strip of magnetic material having a thickness of the order of 12 mils into a closed core section having a plurality of concentric superposed rectangular-like turns defining a window opening in said closed core section, annealing said core section, unwinding said strip from the outside approximately one turn at a time and cutting said strip into cut turns having a length slightly more than one complete turn of said closed core section comprising making a first cut in said strip along one side of said closed core section at a point disposed adjacent one end of said one side, making subsequent cuts in said strip along said one side progressively closer to an opposite end of said one side by spacing said cuts from each other along said one side by $\frac{1}{16}$ to $\frac{1}{8}$ of an inch until a cut is made in said strip at a point disposed adjacent said one side opposite end, stacking said cut turns into a packet whereby said cut turns will be disposed with respect to each other as prior to said unwinding and cutting, and repeating said unwinding, cutting, and stacking with a remainder of said spirally wound closed core section to obtain additional packets by always making a first cut in the strip of said closed core remainder at a point disposed adjacent said one side one end, and then opening said packets and linking them with said winding assembly in the inverse order from which they were formed whereby said one side is located in said winding assembly window opening.

2. A method of making a core section and assembling said core section with an electrical winding assembly having a window opening therein, said method comprising spirally winding a continuous flat strip of magnetic material having a thickness of the order of 12 mils into a closed core section having a plurality of concentric superposed rectangular-like turns defining a window opening, annealing said core section, unwinding said strip from the outside approximately one turn at a time and making a series of cuts in said strip to divide said strip into cut turns having a length slightly less than one complete turn of said closed core section, comprising making a first of said series of cuts in said strip at a point disposed adjacent one end of one side of said closed core section and making subsequent cuts of said series in said strip at points disposed along said one side progressively closer to an opposite end of said one side by spacing said cuts from each other along said one side from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch until a last cut of said series is disposed adjacent said one side opposite end, stacking said cut turns into a packet in the same relationship with respect to each other as prior to said unwinding and cutting, and repeating said unwinding, cutting, and stacking with a remainder of said closed core section to obtain additional packets by always commencing a series of cuts in the wound strip of said closed core section remainder at a point disposed adjacent said one side one end, and then opening said packets and linking them with said winding assembly in the inverse order from which they were formed whereby said one side is located in said winding assembly window opening.

3. A method of forming a magnetic core and linking the same with a preformed electrical coil having a win-

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dow opening therein, said method comprising forming a strip of magnetic core material into a curved core which has radially nested spaced spiral laminar turns, annealing the curved core, dividing the annealed core into packets which have a plurality of spirally arranged approximately single turn length laminar segments comprising cutting the annealed core along only the side thereof which is going to be positioned inside the preformed electrical coil by progressively stagger cutting successive inner laminar turns from one end of said side toward the other end thereof and nesting them into a packet with said turns being disposed in said packet in the same position with respect to each other as said turns were disposed prior to cutting said turns, repeating said operation on said annealed core to obtain additional packets, and opening said packets and linking said packets in the inverse order from which they were formed with the preformed electrical coil by positioning and closing their cut sides inside the electrical coil.

4. A method of forming a magnetic core and linking the same with a preformed electrical coil having a window opening therein, said method comprising forming a strip of magnetic core material into a curved core which has radially nested spaced spiral laminar turns, annealing the curved core, dividing the annealed core into packets which have a plurality of spirally arranged approximately single turn length laminar segments comprising cutting the annealed core along only the side thereof which is going to be positioned inside the pre-

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formed electrical coil by progressively stagger cutting successive inner laminar turns from one end of said side to the other end thereof and nesting them into a packet with said turns being disposed in said packet in the same position with respect to each other as said turns were disposed prior to cutting said turns, repeating said operation on said annealed core to obtain additional packets by always performing said progressive stagger cutting from said one end to said other end, and opening said packets and linking them in the inverse order from which they were formed with the preformed electrical coil by positioning and closing their cut sides inside the electrical coil.

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