Sept. 17, 1963 J. W. RICHARDSON, JR 3,104,364

MAGNETIC CORE CONSTRUCTION

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Fig. 1.

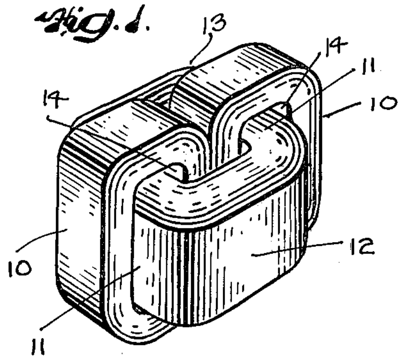

Fig. 2.

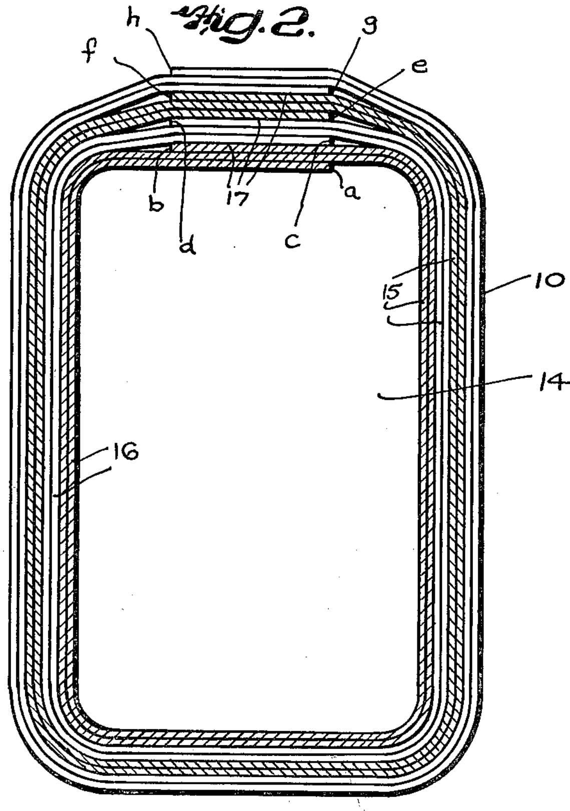

Fig. 3.

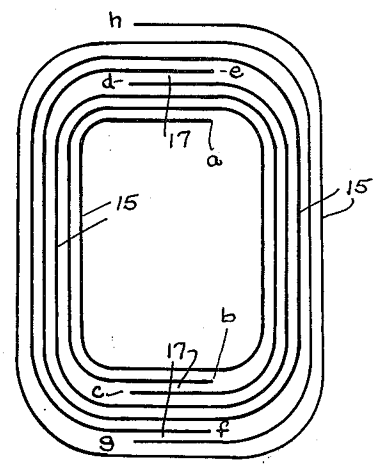

Fig. 4.

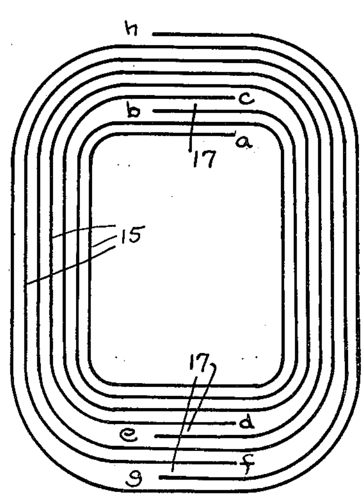

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Fig. 5.

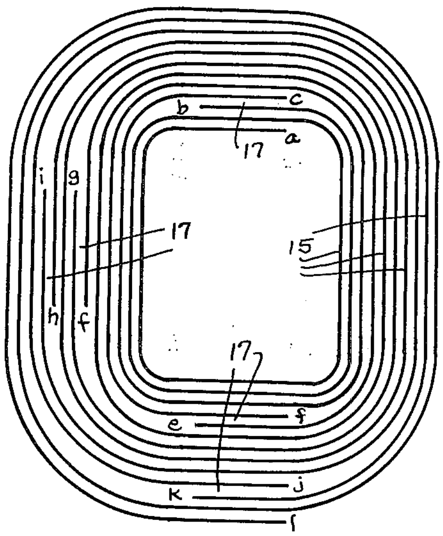


Fig. 6.

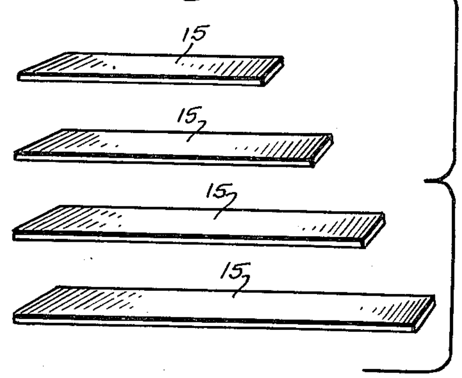


Fig. 8.

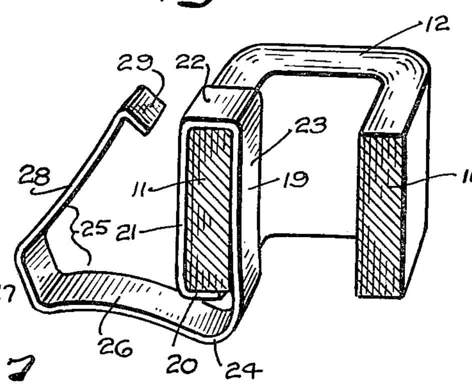
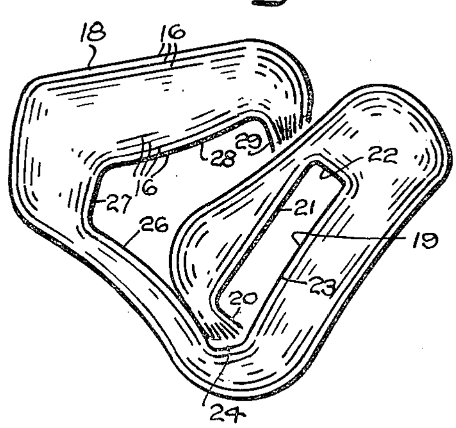


Fig. 7



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MAGNETIC CORE CONSTRUCTION

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This invention relates to magnetic cores and more particularly to an improved construction of a magnetic core for stationary induction apparatus, such as transformers, reactors and the like having pre-formed electrical windings.

Among the principal objects of the present invention is to provide a magnetic core which is formed of a plurality of pre-formed strips of magnetic sheet material each of which is spirally wound to provide a core laminate element of substantially more than a single turn, the complete core assembly being thus formed of any desired predetermined multiple number of such elements assembled one upon another with the adjoining ends of successive elements arranged in overlapping relation to form an overlap type of laminated core. The several individually coiled laminate elements of the core may be of such relatively different spiral lengths as to locate the overlaps between the end portions of successive elements of the core at any desired points about the perimeters of the core laminae and thus such overlaps may be perimetrally spaced to avoid any undesired bunching of the overlaps in a given region of the core. Preferably, however, the overlaps are generally located upon one or more of the sides or ends of the core which project exteriorly of the coil winding.

The core itself, which embraces the conductive coil, is built up of a plurality of preformed spirally wound magnetic strip core elements to provide a laminated core structure of any desired number of laminae, each of said elements extending perimetrally about the conductive coil to the extent of at least one and one-half turns with the proximate ends of successive elements substantially overlapped, in consequence of which a laminated core of the overlap type is provided wherein the aggregate number of laminae forming the core. Thus, by so reducing the number of overlaps or joints between the several strips which form the laminated core, the reluctance in the magnetic circuit of the electromagnetic inductor apparatus of which the core forms a part is reduced to a minimum, such reduction in reluctance being an important objective of the present invention.

Still another important object of the present invention is to provide a laminated construction of magnetic core wherein the several laminae thereof are formed of individual strips of magnetic material suitably cut to length, spirally wound to a shape corresponding to that of the cross-sectional shape of the winding leg of the conductive coil embraced by the core, each strip being so wound as to provide substantially more than a single turn thereof about the winding leg of the transformer coil. The several spirally wound elements which are permanently set to shape and stress-relieved by suitable heat treating, may be readily sprung into open coil form to permit them to be re-assembled successively about one of the legs of the conductive coil winding, the set of each element being such that when it is placed about the coil leg is snugly fits about and conforms to its adjacent inner supporting surface with the result that an exceedingly compact core is formed providing a high space factor. The attainment of this high space factor, as well as the facility with which the pre-formed strips are successively applied to the side leg of a conductive coil to complete the desired magnetic core, constitute important advantages of the present invention.

Still another object of the present invention is to provide a laminated magnetic core which is built up of individual strips of magnetic material which are respectively preshaped and set into spirally wound elements of substantially more than a single turn each, the central opening or windows of the elements being of any desirtd non-circular shape and so graduated in size as to facilitate snugly nesting a series of such elements successively about one another with the innermost element of the series snugly embracing the side leg of a conductive coil having a cross-section generally corresponding to the shape of the central opening or window of the element.

Other objects and advantages of the present invention will be apparent hereinafter, it being understood that the present invention consists, in the combination, construction location and relative arrangement of parts, all as will be described more fully hereinafter, as shown in the accompanying drawings and as finally pointed out in the appended claims.

In the accompanying drawings which are illustrative of the principles of the present invention:

FIGURE 1 is a perspective view of an induction apparatus, in this case a transformer, having a magnetic core as constructed in accordance with the present invention;

FIGURE 2 is an end elevational view of a magnetic core of the present invention showing the construction thereof apart from the apparatus shown in FIGURE 1;

FIGURE 3 is a diagrammatic view illustrating a modified construction of the core;

FIGURE 4 is a diagrammatic view illustrating a further modified construction of the core;

FIGURE 5 is a diagrammatic view illustrating still another modified construction of core embodying the principles of the present invention;

FIGURE 6 is a view showing several of the graduated length strips of magnetic sheet material employed in the construction of the core of the present invention;

FIGURE 7 is a plan view showing a partially opened stocked assembly of the strips as arranged preparatory to successively fitting the strips about the winding leg of the conductive coil of the induction apparatus; and

FIGURE 8 is a perspective view showing the innermost element of the stacked assembly of FIGURE 7 partially wound about the winding leg of the conductive coil of a transformer.

Referring now more particularly to the drawings, it will be observed that the magnetic core **10** of the present invention is shown applied to each of the legs **11—11** of a preformed coil winding **12** of an electromagnetic induction apparatus, e.g., a shell-type transformer **13** as shown. The transformer winding leg **11** to which the core **10** is applied may be of any desired non-circular shape, generally of a quadrangular cross section, either square or rectangular, having its corners rounded off. The magnetic core **10** in its completed form as assembled upon the winding leg of the transformer is built of a plurality of laminations wound spirally about the longitudinal axis of the side leg of the transformer coil **12**, the laminations being formed of a series of spirally wound or coiled elements formed of individual strips of magnetic sheet material, such as high permeability steel strip in which the magnetic flow is lengthwise of the strip and thus traverses a closed path through the magnetic core extending about the coil winding of the transformer. The completed core **10** is provided with a central opening or window **14** which corresponds in shape and size to that of the transformer winding leg **11** and thus the core snugly embraces and is supported by the conductive coil structure of the induction apparatus.

For producing the magnetic core **10** of the present invention, there is initially provided a plurality of individual strips 15 of suitable sheet material having high permeability favoring flow of magnetic flux in a direction running lengthwise of the strip. As many of these strips 15 are pre-cut to length as are required for the building of a core of the desired number of laminations, each strip 15 being of a length sufficient for it to be wrapped about the conductive coil to the extent of at least one and one-half turns. For all practicable purposes, in accordance with the principles of the present invention, the strips 15 may each extend from 1½ to as much as 3 turns about the conductive coil. The several strips 15 which comprise a single core assembly are respectively graduated in length, as shown in FIGURE 6, so that the strips constituting a given core set may be respectively wound to their proper shape and size required for subsequent nesting thereof together to form the laminated core assembly 10.

Each of the strips 15 is pre-formed and set to the general cross-sectional shape of the side leg 11 of the transformer coil, each such strip being spirally wound into a coil formation of substantially more than one and one-half turns. When spirally wound into such coiled shape the strip is heat-treated to relieve it of all such stress as might impair its magnetic properties, which heat-treating or annealing also imparts to the strip a permanent set tending to maintain it in its coiled form.

FIGURE 2 shows a construction of a laminated magnetic core wherein the several strips 15 of predetermined varying length are pre-formed into spirally wound core elements 16 of approximately 2 turns each, the end of each coiled strip being so extended beyond the median plane of the core as to provide for a substantial overlap 17 between the end portions of the successively nested core elements. Thus, as clearly appears in FIGURE 2, the innermost core element 16 which immediately embraces the side leg 11 of the transformer coil 12 is provided with inner and outer terminal portions *a* and *b*, while the succeeding core elements are respectively provided with inner and outer terminal portions *c—d*, *e—f*, etc.

It will be noted that the several spirally wound core elements 16 are nested together with the turns thereof all extending in the same direction, that is, counter-clockwise from the points *a*, *c* and *e* as viewed in FIGURE 1, so that in effect the several core elements conjointly form a unidirectional spirally wound laminated core with overlaps 17 of substantial extent between the adjoining end portions of the successively nested elements.

By forming the magnetic core 10 entirely of core elements 16 of two turns each, as in the construction of FIGURE 2, all of the overlaps 17 are in alinement in the same end or side of the core. However, by forming the core elements of one and one-half turns each, as diagrammatically shown in FIGURE 3, the overlaps 17 are distributed equally between opposite ends or sides of the core, which same effect would also be obtained by forming all of the core elements of two and one-half turns each or of any number of whole turns plus one half turn.

The distribution of overlaps 17 between opposite sides or ends of the magnetic core may also be obtained by nesting together core elements which are alternately of two turn and one and one-half turn formation, as shown diagrammatically in FIGURE 4, or by alternating core elements formed of whole turns exceeding one in number with those formed of any number of whole turns plus one half turn.

Obviously, the location and spacing of the overlaps perimetrally about the core may be varied as desired by the selected use of pre-formed core elements spirally wound to such length as to present the overlaps 17 in the positions found to be most advantageous from the standpoints of minimum reluctance in and operating efficiency of the magnetic circuit and compactness of the core where a high space factor is of importance. Thus, FIGURE 5 illustrates diagrammatically a construction wherein core elements of varying degrees of turns are nested together in such relative relation as to locate the several overlaps 17 in three different sides of the completed core assembly.

In all cases, the several core elements which comprise a given laminated core assembly are initially pre-formed and set to the shape which they are required to assume in the completed core. They are then nested one within the other to form a stack from which they are individually removed for reassembly about the winding leg of the closed conductive coil of the transformer or other such induction apparatus. The stack of nested core elements prior to assembly about the coil of the induction apparatus would appear more or less exactly as it does when re-assembled thereon, the re-assembly upon the side leg of the conductive coil being effected by removal of the innermost element from the stack and placement thereof about the conductive winding, followed by removal of the remaining core elements from the stack and replacement thereof in their proper sequence around the winding leg to form thereabout the final laminated core, such as is designated by the reference numeral 10 in FIGURE 1.

To facilitate removal of the core elements 16 sequentially from the stack thereof prepared for a given construction of core, the several core elements may be each partially sprung open and nested together to form thereof a stack 18 as shown in FIGURE 7, wherein the opposite terminal edges of the core elements 16 are designated *a—b*, *c—d*, *e—f*, etc., in correspondence with the designations shown in FIGURES 2 to 5.

FIGURE 8 illustrates in perspective the innermost core element 16 of the stack 18 as said element appears when removed from the stack and assembled partially about the side leg of the transformer coil structure. This element 16 is generally typical of all of the core elements comprising the stack 18, the several elements thereof differing only in respect to their overall median length and in certain instances in the degree of turns per element, as where core elements of different turn degree are to be alternated when nested together to provide for spacing of the overlaps 17 about the perimeter of the core as described hereinabove.

In all instances, each of the core elements 16 is preformed and set to shape to provide the same with an inside whole turn loop 19 having an inner overlap section 20, a side section 21, an end section 22, an opposite side section 23 and an end section 24 opposite the overlap section 20, the end section 24 being continued to form at least a substantial part of a second loop closely embracing the inside single turn loop. The core element 16 as shown in FIGURE 8 is of two turn looped formation, wherein the inside whole turn loop 19 is embraced by a second whole turn outer loop 25 formed in continuation of the end section 24 and having a side section 26, an end section 27, an opposite side section 28 and an outer overlap section 29.

The core elements, of which that shown in FIGURE 8 is typical, may be readily opened up or spread apart for assembly thereof about the winding leg of the transformer coil as shown in FIGURE 1, the sequential assembly of the several core elements about the closed conductive coil being effected easily and without subjecting the elements to any such undue bending or stretching thereof beyond the elastic limit as might impair the magnetic properties of the core strips.

It will be noted that in the magnetic core as constructed in accordance with the principles of the present invention each of the pre-formed core elements is formed of a strip of magnetic sheet material of a length substantially greater than the mean perimetral length of the core and that the several overlapped joints between adjoining ends of the radially nested core elements are respectively located at points located a substantial number of degrees beyond the point whereat a given strip meets itself to form a single turn thereof, in consequence of which the aggregate number of overlapped joints in the completely assembled laminated core is substantially less than the aggregate number of strip layers present in the core as the same are counted radially outward from the innermost core layer through a section of the core free of any overlaps. Thus, in the construction shown in FIGURE 2 wherein the core as shown comprises a total of eight layers of strip material, it includes only three overlaps, while in the construction of FIGURE 3 there are only three joints for six layers of strip material. In the FIGURE 4 arrangement, there are only three overlaps for seven layers of strip material, and in that of FIGURE 5, where as many as eleven layers of strip material are included in one side leg of the core, only five joints are provided. It will be understood, of course, that FIGURES 2 to 5 are only illustrative and that while in cores produced in accordance with the present invention the laminations may be of any desired number, the aggregate number of overlaps in the core will always be substantially less than the number of its laminations. This reduction in the number of joints present in the core materially reduces the reluctance in the magnetic circuit with increased operating efficiency and improved performance of the induction apparatus.

It will be understood, of course, that the present invention is susceptible of various changes and modifications which may be made from time to time without departing from the real spirit or general principles thereof, and it is accordingly intended to claim the same broadly, as well as specifically, as indicated by the appended claims.

What is claimed as new and useful is:

1. A magnetic core for electric induction apparatus comprising a plurality of concentrically stacked spirally wound core-forming elements formed of magnetic sheet material, all of said elements being of a generally rectangular, hollow configuration conforming generally to the cross-sectional shape of the coil embraced by the magnetic core, each such spirally wound element including substantially more than a single whole turn and being of such convolute length that in the concentric stack thereof the proximate ends of adjoining elements are overlapped to form joints which respectively lie between non-jointed lengths of the sheet material forming the core.

2. A magnetic core for electric induction apparatus comprising a plurality of radially nested core-forming elements respectively formed of magnetic strip material of uniform width and thickness precut to predeterminedly different lengths, each such element being spirally wound into the shape of a hollow structure corresponding to the cross-sectional shape of the coil embraced by the magnetic core, the several elements respectively having central openings of gradually increasing size adapting them to be nested together to form a laminated structure, each element being of such convolute length as to provide it with one whole turn and at least one half of a second turn, the outer end portion of each spirally wound element being overlapped with respect to the inner end portion of its embracing element in the radially nested series of such elements, the outer end portion of each core-forming element being so spaced angularly beyond the first single whole turn thereof as to overlie an uninterrupted length of the strip material forming the element, whereby the aggregate number of overlapped joints in the laminated core is substantially less than the aggregate number of layers of strip material counted radially outward from the innermost core layer through a section of the core free of overlaps.

3. A magnetic core for electric induction apparatus comprising a plurality of concentrically stacked spirally wound coils of magnetic sheet material of uniform width and thickness, said coils being respectively formed of strips of said material initially cut to predetermined different lengths to provide thereof coils of graduated size adapted to be nested together in predetermined sequence, each such coil being of a convolute length substantially greater than the mean perimetral length of the core, the adjoining ends of the nested coils being overlapped at regions respectively located a substantial number of degrees beyond the points of completion of the first whole turns of the coils.

4. A magnetic core for electric induction apparatus comprising a plurality of concentrically stacked spirally wound coils of magnetic sheet material of uniform width and thickness, said coils being respectively formed of strips of said material initially cut to predetermined different lengths to provide thereof coils of graduated size adapted to be nested together in predetermined sequence, each such coil being of a convolute length substantially greater than the mean perimetral length of the core, the adjoining ends of the nested coils being overlapped at regions respectively located a substantial number of degrees beyond the points of completion of the first whole turns of the coils, said overlaps being respectively disposed between radially spaced intermediate portions of adjoining pairs of said nested coils.

5. A magnetic core for electric induction apparatus comprising a plurality of concentrically stacked spirally wound coils of magnetic sheet material of uniform width and thickness, said coils being respectively formed of strips of said material initially cut to predetermined different lengths to provide thereof coils of graduated size adapted to be nested together in predetermined sequence, each such coil being of a convolute length substantially greater than the mean perimetral length of the core, the adjoining ends of the nested coils being overlapped, at regions respectively located a substantial number of degrees beyond the points of completion of the first whole turns of the coils, said overlaps being each disposed between intermediate portions of the same coils which have their ends overlapped.

6. A magnetic core for electric induction apparatus comprising a plurality of concentrically stacked spirally wound coils of magnetic sheet material of uniform width and thickness, said coils being respectively formed of strips of said material initially cut to predetermined different lengths to provide thereof coils of graduated size adapted to be nested together in predetermined sequence, the adjoining ends of the nested coils being overlapped, said overlaps being each disposed between intermediate portions of the same coils which have their ends overlapped.

7. In a magnetic core as defined in claim 6 wherein each of the coils of magnetic sheet material is spirally wound to the extent of from 1½ to 3 turns, whereby its outer end portion overlies an inner complete convolution thereof.

8. In a magnetic core as defined in claim 6 wherein each of the coils of magnetic sheet material comprises 2 full turns with the inner and outer terminal portions thereof projecting in opposite directions substantially beyond the transversely extending median plane of the coil.

9. In a magnetic core as defined in claim 6 wherein the coils are polygonal in transverse section to thereby afford a correspondingly shaped assembly thereof.

10. In a magnetic core as defined in claim 6 wherein the nested coils are polygonal in transverse section to thereby afford a correspondingly shaped assembly thereof, and the overlapped adjoining ends of the nested coils are distributed respectively at least between two different sides of said core, whereby the same are angularly spaced relative to one another about said coil.

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