Nov. 2, 1943. P. L. CHRISTENSEN 2,333,464

STEPPED OUTLINE WOUND CORE

Filed Nov. 29, 1940

Fig. 1.

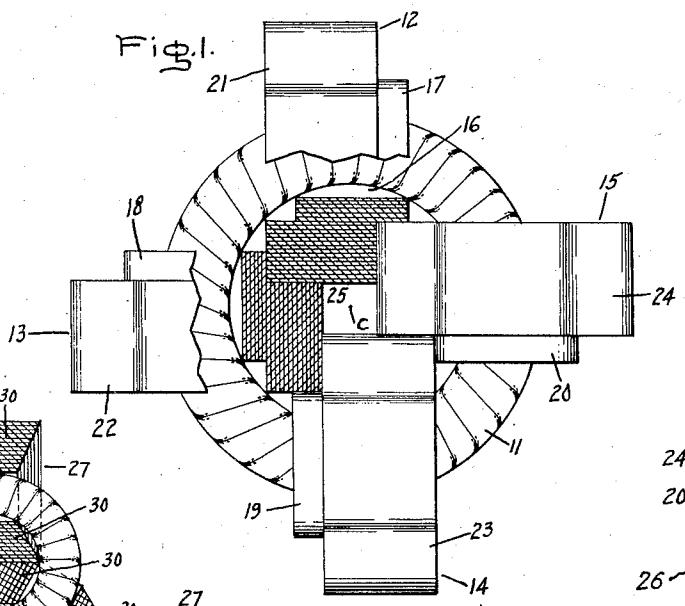


Fig. 4.

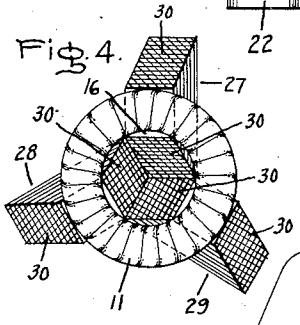


Fig. 3.

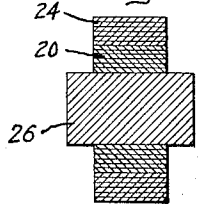
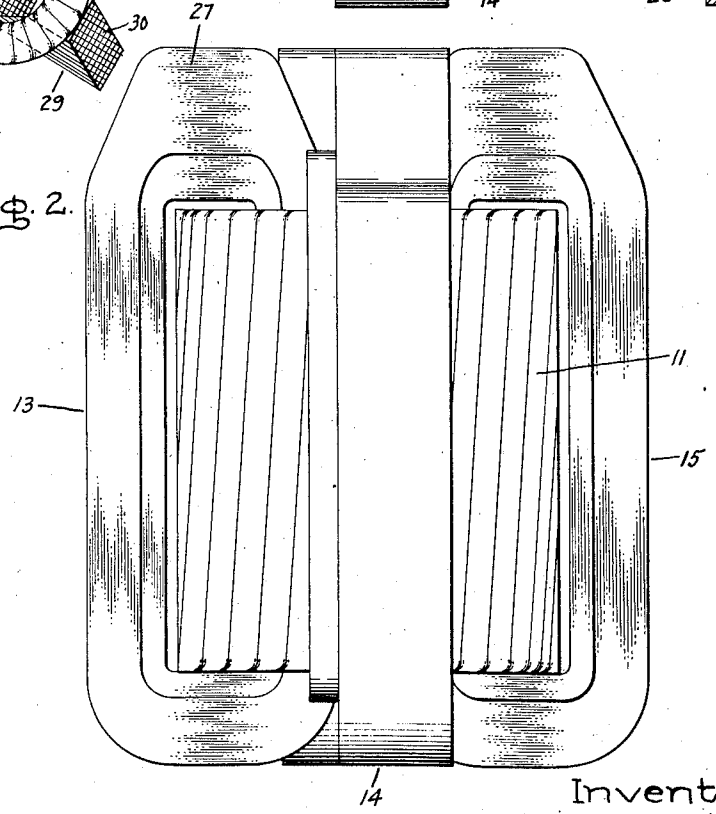


Fig. 2.



Inventor:
Paul L. Christensen,
by Harry E. Dunham
His Attorney.

Patented Nov. 2, 1943

2,333,464

UNITED STATES PATENT OFFICE

2,333,464

STEPPED OUTLINE WOUND CORE

Paul L. Christensen, Pittsfield, Mass., assignor to General Electric Company, a corporation of New York

Application November 29, 1940, Serial No. 367,779

3 Claims. (Cl. 175—356)

My invention relates to electromagnetic induction apparatus and it concerns particularly apparatus of the type employing magnetic cores composed of magnetic strip material spirally wound flatwise into compact coils of strip.

It is an object of my invention to provide an improved construction for wound core transformers and reactors having a circular winding window and having magnetic core elements passing through the winding window and radially disposed around the axis of the winding structure with high space factor of magnetic material within the winding window. Other and further objects and advantages will become apparent as the description proceeds.

In carrying out my invention in its preferred form, I utilize wound-strip core elements employing strip material of uniform width. The layers of strip constituting the outside portions of the core elements are laterally displaced in order to produce core cross-sections which may be interfitted to form a core which has a stepped outline within the winding window and largely occupies the space therein.

A better understanding of the invention will be afforded by the following detailed description considered in connection with the accompanying drawing, and those features of the invention which are believed to be novel and patentable will be pointed out in the claims appended hereto. In the drawing Fig. 1 is a plan view of one embodiment of my invention with two of the core elements partially broken away and shown in cross-section. Fig. 2 is an elevation of the apparatus shown in Fig. 1. Fig. 3 is a diagram illustrating a step in the assembling process. Fig. 4 is a plan view, partially in section, of another embodiment of my invention. Like reference characters are utilized throughout the drawing to designate like parts.

The electromagnetic induction apparatus shown in Figs. 1 and 2 of the drawing, which may be either a transformer or a reactor, for example, consists of a conductive winding structure 11 and core means consisting of four radially disposed core elements 12, 13, 14 and 15. It will be understood that the winding structure shown as a fully preformed form-wound structure insulated as a unit, may include one or more electrically independent windings and in the case of a transformer would include at least one primary winding and one secondary winding.

The winding structure 11 is in hollow cylindrical form with a magnetic or longitudinal axis (the axis passing through the point C perpendicular to the plane of the paper in Fig. 1) surrounded by portions of the winding structure adapted to be encircled by the magnetic core elements. For convenience in nomenclature, the portions of the winding structure encircled by the core elements are referred to as sides. A plane passing perpendicularly through the longitudinal axis of the winding structure 11 will cut an annular cross-section bounded by a pair of concentric circles, and planes passing through the longitudinal axis of the winding structures will cut oblong or elongated rectangular longitudinal sections.

The core elements 12 to 15 inclusive, constituting a magnetic core means, are composed of material in strip form wound spirally flatwise in layers or turns, each surrounding an underlying layer. The layers are in close surface contact along at least one side of the core element, preferably the side within the winding window 16 of the winding structure 11. In the embodiment of my invention represented by Figs. 1 and 2, the core elements consist of separate portions 17 to 24 inclusive, with outer portions 21 to 24 inclusive surrounding inner portions 17 to 20 respectively and displaced laterally therefrom. Accordingly, a core section is produced with a stepped outline as indicated in Fig. 1, and the core elements are so interfitted that the circular winding window 16 is substantially filled in order to obtain good space factor of the magnetic material within the winding window.

The apparatus illustrated in Figs. 1 and 2 of the drawing has the depths of the outside portions of the various core elements approximately one-half the widths of the strip material of which the core elements are formed, so that about one-half of the surface of the outside layer of each of the outside core portions 21 to 24 inclusive abuts closely against the edges of the strip material forming the outside portion of the adjacent core element which is displaced 90° therefrom. In this manner a cooling duct 25 is provided for cooling fluid such as oil in which the magnetic induction apparatus may be immersed. The inside portions 17 to 20 of the core elements 12 to 15 consist of slightly less than one-third many layers of strip as the entire core elements in order that the stepped-outline core section will fit a circumscribed circle.

The production of the separate individual core portions 17 to 24, inclusive, is not a part of my invention and need not be described in detail. These core portions may be built up in the manner described in the copending application of Jacob J. Vienneau, Serial No. 318,868, filed Feb-

ruary 14, 1940, which application issued as Patent 2,305,649 and December 22, 1942. It will be observed, however, that the strip material forming the outer portions 21 to 24 is of the same width as the material forming the inner portions 17 to 20 inclusive. Needless to say, this is an advantage from the standpoint of manufacturing operations and of maintaining adequate stock of strip material. This feature is of particular advantage during the annealing or heat treatment of the strip material of which the core elements are formed. As explained more in detail in the Vienneau application, it is desirable to heat-treat the strip material in coils of strip having the exact size and shape which the finished core portions are to have in order to bring out the desirable magnetic properties of the magnetic material and in order to have it free from strains. However, owing to the fact that the strip material is of the same width in the inner and outer core portions, it is unnecessary to have the inner and outer core portions offset or even cut apart during the annealing operation. This eliminates the need for fillers or mandrels of complicated form. It will be understood, of course, that it would not be permissible to leave a portion of the turns of strip material unsupported while it is subjected to heat treatment.

The core material forming one of the core elements 15, for example, may be heat-treated by winding it upon a mandrel of simple form 26 (Fig. 3) with a slightly greater cross-sectional size than one of the longitudinal sections of the winding structure 11. The inner and outer core portions 20 and 24 of the core element 15 are then wound upon the mandrel 26 without attempting to offset the core portion 24 from the core portion 20. The portions 20 and 24 may be composed of the same continuous strip. After the heat treatment has been completed and the material has sufficiently cooled, the coils of strip are removed from the mandrel 26 and applied to the winding structure. As explained in greater detail in the aforesaid Vienneau application, this may be done by removing turns of strip in sections of two or three turns from the heat treated coil and cutting these sections apart. The turns of strip are applied to the side of the winding structure 11 in sequence beginning with what was the inside turn of the heat-treated coil or strip until all the turns of strip have been applied and are in the same sequence with the same size and shape that they had in the original coil of strip. After the core portion 20 has been built up, the section of strip which is to constitute the inside section or group of turns of strip of the core portion 24 is laterally displaced and the subsequent turns of strip are applied around the inner turns of strip of the core portion 24 to build up the offset structure shown in Figs. 1 and 2, and it will be noted that each portion has a plurality of layers directly overlying each other. As shown in Fig. 2, the turns of strip may be in close surface contact all around each core element, except at the top ends 27, where spacings are provided between every few turns of strip to facilitate the application of the strip material to the winding structure without binding. These spacings are the result of shims laid in between the corresponding portions of the turns of the original coils of strip before they are heat-treated. This feature, however, is disclosed in the aforesaid Vienneau application and is not a part of my present invention.

Although in Figs. 1 and 2 I have illustrated core means consisting of four core elements each consisting of two separate off-set portions, it will be understood that my invention is not limited to this precise number of core elements nor to having the core elements divided into only two portions. The core elements may be divided into a greater number of off-set portions to produce interfitting cross-sections or, if desired, each layer of magnetic strip material may be off-set slightly from the underlying layer of strip material, thus forming a separate core portion of the core element. For example, in the arrangement shown in Fig. 4, there are three core elements 27, 28 and 29. The layers of strip in each core element are off-set so as to form rhombic cross-sections 30. The degree of off-set of the layers is such that the rhombus angles are alternatedly 60 and 120 degrees so that the three core sections fit closely together within the winding window 16, forming a hexagon circumscribed by the inside surface of the hollow cylindrical winding structure 11. It will be observed that, as in the arrangement of Figs. 1 and 2, the edges of the strip material in one core element abut the outside surface of the outside layer of strip material in the adjacent core element angularly displaced therefrom.

In accordance with the provisions of the present statutes, I have described the principle of operation of my invention together with the apparatus which I now consider to represent the best embodiment thereof but I desire to have it understood that the apparatus shown is only illustrative and that the invention may be carried out by other means.

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

1. Electromagnetic induction apparatus comprising a conductive winding structure and magnetic core means linking it, said winding structure being in hollow cylindrical form with a circular winding window surrounded by sides adapted to be encircled by core elements, said winding structure having an annular cross-section cut by a plane perpendicular to the longitudinal axis of the winding structure and oblong longitudinal sections cut by planes through the said axis, said core means comprising four core elements radially disposed around the winding structure axis, passing through the winding window and around the sides of the winding structure, each element being built up of magnetic strip material spirally wound flatwise around the winding structure and having successive layers of strip in close surface contact within the winding window, said core elements being fitted within the winding window for high space factor, each element having two portions one outside the other, and laterally offset, the magnetic strip material of the portions of the core elements having a single uniform width, the outside portion of each core element having one side of the outside layer of strip in abutment with the edges of the strip material forming the outside portion of the adjacent core element which is displaced 90°.

2. Electromagnetic induction apparatus comprising a conductive winding structure and magnet core means linking it, said winding structure being in hollow form with a winding window surrounded by sides adapted to be encircled by core elements and with a longitudinal or magnetic axis passing through the winding window, said core means consisting of four core elements radially disposed around the winding structure axis, passing through the winding window and

around the sides of the winding structure, each element being built up of magnetic strip material spirally wound flatwise around the winding structure and having successive layers of strip in close surface contact within the winding window, said core elements being fitted in the winding window for high space factor by having each core element in two portions laterally offset one outside the other, the magnetic strip material of the portions of the core elements having a single uniform width, the outside portion of each core element having one side of the outside layer of strip in abutment with the edges of the strip material forming the outside portion of the adjacent core element which is displaced 90° therefrom.

3. Electromagnetic induction apparatus comprising a conductive winding structure and magnetic core means linking it, said winding structure being in hollow form with a winding window surrounded by sides adapted to be encircled by core elements and with a longitudinal or magnetic axis passing through the winding window, said core means comprising a plurality of magnetic core elements radially disposed around the axis of the winding structure passing through the winding window and around the sides of the winding structure, each element being built up of magnetic strip material wound flatwise in layers one over the other around the sides of the winding structure and comprising strip material continuous for a plurality of turns, said core elements being interfitted in the winding window for high space factor by having each core element in a plurality of portions laterally offset one outside the other with said portions each having a plurality of layers directly overlying each other, the outside portion of each core element having a part of the outer surface of the outside layer of strip against the edge of the strip material forming the outside portion of the adjacent core element displaced angularly therefrom, the magnetic strip material of the portions of the core elements having a single uniform width.

PAUL L. CHRISTENSEN.