April 24, 1951 T. R. SPECHT 2,550,127

WOUND CORE FOR ELECTRICAL INDUCTION APPARATUS

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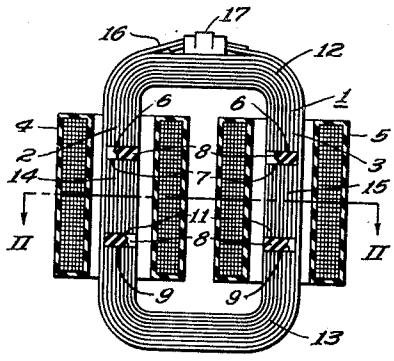


Fig. 1.

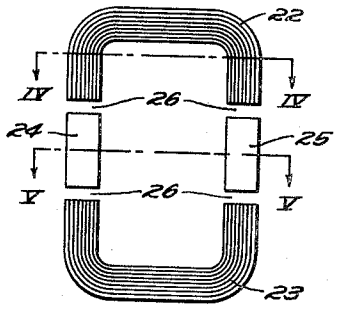


Fig. 3.

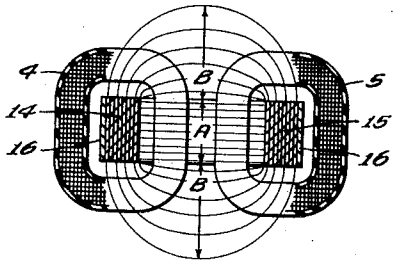


Fig. 2.

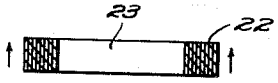


Fig. 4.

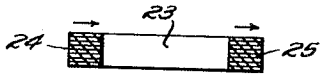


Fig. 5.

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WOUND CORE FOR ELECTRICAL INDUCTION APPARATUS

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9 Claims. (Cl. 171—242)

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My invention relates to electrical induction apparatus, and particularly to the iron core structure comprising the magnetic circuit of such apparatus.

Inductive reactance coils or reactors are frequently employed as current limiting devices which serve to limit to a safe value the currents that may flow in an associated power circuit when abnormal circuit conditions, such as short circuits or heavy overloads, occur. In many applications of such reactors, iron cores are employed. In order to give the device its proper characteristics, it is necessary to provide an air gap in the path of the magnetic circuit.

In order to minimize the effect of fringing, the total gap is broken down into a number of short gaps. Bundles of laminations of magnetic material are put together to form a core section and are separated from another section by an insulating filler or solid insulating material. It is common practice to stack these laminations as evenly as possible and then impregnate them in some suitable compound that will harden and cause the laminations to adhere to each other to form a solid block from the bundle of laminations.

Magnetic steels have been developed having greater permeability and lower watts loss per unit volume, or weight, than that found in commercial grades of hot rolled silicon steel at the same densities, when the lines of magnetic flux pass through the steel substantially in a preferred direction, that is, in the direction of rolling the strip in forming it.

In order to make efficient use of such magnetic material, the length of the strip should be so positioned in the core structure that the lines of magnetic flux pass through the strip in the direction of rolling. Such magnetic core loops have been formed by winding successive layers of magnetic sheet material flatwise layer upon layer about a rectangular mandrel, annealing the wound layers to remove strains caused by winding, bonding the wound layers together by impregnating the spaces between the successive layers with a bonding or filling material, and baking the core loop to harden the bonding material, thereby providing a solid or non-yielding laminated structure having a film interlayer bond for all portions of the layers of sheet steel which is beneficial in producing a smooth cut surface forming the face of the butt joints.

Such core loop structures of magnetic material have been used in transformer cores. When the steel ribbon forming the core is wound layer upon layer, the layers bonded together and baked

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to form a solid loop structure, the loop is then cut into separate upper and lower portions. The layers of the resulting separable core portions are held together as a solid mass, so that there is no vibration or relative movement of the layers and these core portions are assembled about the transformer windings with the adjoining ends of the core portion in engagement to form smooth butt joints.

The use of such wound cores in reactors can result in higher than normal core losses in some designs. One of the causes of this is that in certain reactors a relatively high leakage flux exists between the two winding legs of the core structure. Since the shortest path for the flow of this leakage flux between the two winding legs of the core is directly across the window outlined by the core structure, this leakage flux will be the greatest in this area and will leave the core and reenter the core directly through the flat side of the layer of magnetic sheet steel outlining the window. This results in large iron losses due to the eddy currents in the core leg steel.

It is an object of my invention to provide a magnetic core structure of the wound core type for use as the magnetic circuit path of reactors in which the losses due to leakage flux is greatly reduced from what it would be with the conventional arrangement of the parts of the wound core.

Other objects and advantages of the invention will be apparent from the following description of a preferred embodiment of the invention, reference being had to the accompanying drawing, in which:

Figure 1 is an elevational view partly in section of a reactor core and coil assembly,

Fig. 2 is a sectional view taken on the broken line II—II of Fig. 1,

Fig. 3 is an elevational view of the parts of the core structure arranged in accordance with the invention,

Fig. 4 is a sectional view taken along the broken line IV—IV of Fig. 3, and

Fig. 5 is a sectional view taken along the broken line V—V of Fig. 3.

Referring to the drawing, and particularly to Figs. 1 and 2 thereof, a core loop structure 1 is shown formed by winding a continuous ribbon of magnetic sheet steel on a substantially rectangular mandrel, annealing the steel after winding, impregnating the steel to form a bonded core structure, and cutting the formed core loop into parts as described above.

As shown, the core loop is provided with two

parallel winding leg portions 2 and 3 surrounded by coils or windings 4 and 5. The core loop is shown cut at four places, that is, adjacent the ends of each of the two opposite sides of the core loop comprising the winding leg portions thereof. These cuts provide the separated cut surfaces 6 and 7 at the upper ends of the winding leg portions of the core, as shown in Fig. 1, and the surfaces 9 and 11 at the lower ends of the winding leg portions of the core loop to form butt joints between them. Insulating material shown as blocks 8 is provided between the cut surfaces of each of the four joints to space the cut surfaces apart forming air gaps at the joints. These joints separate the core loop into two U-shaped yoke parts 12 and 13 and two winding leg parts 14 and 15 positioned between the yoke parts of the reassembled core loop, the several parts being held together by means of a steel strap 16 that is positioned about the core loop and fastened by means of a crimped sleeve coupling 17 while the strap 16 is under tension.

In a reactor core of this type there is a considerable magnetomotive force between the winding legs of the core. This results in leakage flux which takes the general pattern shown in Fig. 2. A large portion of this leakage flux will follow the direct path between the two winding legs since this is the shortest path. This portion of the leakage flux is identified as part A in Fig. 2 and flows through the space within the window surrounded by the core loop. Another portion identified as part B represents a smaller amount of leakage flux, since the reluctance of this longer path is greater. The losses due to the part B is small, since the amount of this flux is small while the losses due to the part of the leakage flux A is greater, because the amount of flux is greater and because in the conventional way of arranging the iron in a wound core loop as shown in Figs. 1 and 2, this flux comes directly out of the flat side of the laminations causing high eddy currents, which eddy currents flow within the laminations following a circular path about the lines of magnetomotive force, that is about the lines representing the direction of the path of the leakage flux.

In accordance with my invention the winding leg parts 24 and 25 shown in Fig. 3 are rotated on their axis so that the planes of the lamination layers are at right angles to the planes of these laminations prior to cutting. This will result in the leakage flux in the part A, passing directly between the winding leg parts of the core, leaving and entering these parts through the edges of the lamination layers. Consequently, the losses will be reduced because there is lack of space for any appreciable eddy current to develop within the core.

The arrangement of the lamination layers is shown in Figs. 4 and 5 in which the layers in the U-shaped yoke parts of the cores 22 and 23 are in the direction shown by the arrows in Fig. 4 corresponding to placing layer upon layer of the wound ribbon one about the other in winding, while the direction of the lamination layers in the winding core parts 24 and 25 is as shown in Fig. 4, that is, in planes extending directly across the window about which the core loop is positioned.

When the core parts are assembled in the relative position shown in Figs. 3, 4 and 5, the edges of the layers of magnetic sheet steel on the side of the air gaps 26 occupied by the yoke parts 22 and 23 will be in the direction shown in Fig. 4

while the direction of the edges of the lamination layers on the opposite sides of the air gaps corresponding to the direction of the layers in the parts 24 and 25 will be in the direction shown in Fig. 5, which is at right angles to the direction shown in Fig. 4. Thus the part A of the flux shown in Fig. 2 will pass directly from the edges of the lamination layers 24 and 25 as shown in Figs. 3 and 5, and the losses resulting from the part B of the leakage flux will be only slightly changed, since only a relatively small part of the leakage flux takes the longer path. For clearness in illustrating the relationship between the parts of the structure comprising the magnetic circuit, Figs. 3, 4 and 5 show only structure comprising the magnetic circuit. It will be appreciated that the core and coil assembly structure is completed in the same manner as shown in Fig. 1.

The amount of benefit to be expected from this construction is difficult to predict by calculation. One particular structure constructed in accordance with Figs. 3, 4 and 5 has shown 33% lower losses when the core legs are rotated 90° as shown in Figs. 3 and 5 below the losses resulting when the core leg parts are positioned as shown in Figs. 1 and 2. It is desirable that the number of layers of the core made in winding the core structure is such that the cross sectional area of the magnetic path will be a square as shown in Figs. 4 and 5, so that the surfaces outlining the magnetic path will be the same in either position of the winding leg portions 24 and 25. That is, the square ends of these parts will be positioned opposite square ends of the yoke parts 22 and 23.

The location of the air gaps 26 may be varied somewhat but will, in general, be adjacent the ends of the winding leg portions of the core structure. Intermediate gaps in the core portions 24 and 25 may also be provided along the lengths of these winding leg parts if it is desired to distribute the total length of air gap in a winding leg portion so that the total gap will consist of a larger number of gaps of lesser length per gap. In any case, the direction of the layers in the winding core parts between the yoke parts 22 and 23 will be as shown in Fig. 5.

It will be apparent to those skilled in the art that modifications in the structure illustrated and described, and the method of applying it may be made within the spirit of my invention, and I do not wish to be limited otherwise than by the scope of the appended claims.

I claim as my invention:

1. A magnetic core structure for a current-limiting reactance device comprising a substantially rectangular magnetic circuit loop formed from a ribbon of magnetic sheet steel wound flatwise layer upon layer, two parallel sides of the rectangular loop serving as winding leg portions of the core and provided with air gaps therein adjacent the opposite ends thereof separating the central parts of the winding leg portions of the core from the end parts of the magnetic circuit loop, the layers of magnetic sheet steel in the end parts of the magnetic circuit loop being arranged with their flat sides facing the window in the core, and the central parts of the winding leg portions of the core loop between the air gaps being positioned with their edges facing the window in the core.

2. The method of making a core structure for an induction device comprising forming a rectangular looped magnetic core having two sub-

santially parallel winding leg portions by winding a ribbon of thin flat magnetic sheet steel upon itself to form a closed loop about a window, impregnating the spaces between the successive layers of the ribbon of magnetic material with bonding material and baking the core to harden the binding to bond the adjacent layers of said core solidly together, cutting the bonded core loop transversely adjacent each end of each winding leg portion to form two U-shaped core loop end parts and two winding leg parts therebetween, assembling the cut parts of the core loop with insulating material between the cut surfaces to space them apart and form air gaps at the joints in the magnetic circuit, and with the winding leg parts turned on their axis after cutting so that the edges of the lamination layers at the cut joints are at right angles to the edges of the lamination layers on the opposite sides of the air gaps, and placing a resilient band of metal under tension about said loop for maintaining a substantially constant pressure on said joints.

3. In a magnetic structure for electrical induction apparatus, a core loop formed from a ribbon of magnetic sheet steel wound flatwise layer upon layer for a sufficient number of layers to form a square cross-section of the magnetic circuit path, the core loop having a substantially rectangular window therein, the several layers being bonded together to form a solid mass, said loop being provided with butt joints adjacent the ends of two opposite sides of the core loop separating the core loop into two U-shaped yoke parts and two winding leg parts, solid blocks of insulating material between the butt-joint surfaces of the several core parts providing air gaps at the joints, the winding leg parts being positioned with the edges of the lamination layers at the joints at right angles to the edges of the lamination layers on the opposite sides of the air gaps and the planes of the lamination layers in the winding leg parts extending across the window of the core loop, and a resilient band of metal under tension about the loop for holding the parts together and maintaining a substantially constant pressure on the joints.

4. A magnetic core structure for a current-limiting reactance device comprising a substantially rectangular magnetic circuit loop formed from a ribbon of magnetic sheet steel wound flatwise layer upon layer, the magnetic circuit path of the core having a square cross-sectional area, two parallel sides of the rectangular loop serving as winding leg portions of the core and provided with air gaps therein adjacent the opposite ends thereof separating the central parts of the winding leg portions of the core from the end parts of the magnetic circuit loop, the core parts of the two parallel sides between the air gaps being positioned with the planes of the layers of magnetic sheet steel at right angles to the direction of lamination layers in the end pieces of the core loop at the air gaps.

5. A magnetic core structure for a current-limiting reactance device comprising a core loop formed from a ribbon of magnetic sheet steel wound flatwise layer upon layer and having a substantially rectangular window therein, the magnetic circuit path of the core having a square cross-section area, the several layers being bonded together to form a solid mass, two sides of the core on opposite sides of the rectangular window serving as winding leg portions of the core and each having a pair of air gaps, one adjacent each end of the winding leg portion, the core part between the air gaps in each winding leg portion being positioned with the planes of the lamination layers of magnetic sheet steel extending across the window surrounded by the core loop.

6. A magnetic core structure for a current-limiting reactance device comprising a substantially rectangular magnetic circuit loop formed from a ribbon of magnetic sheet steel wound flatwise layer upon layer, the magnetic circuit path of the core having a square cross-sectional area, two parallel sides of the rectangular loop serving as winding leg portions of the core and provided with air gaps therein adjacent the opposite ends thereof separating the central parts of the winding leg portions of the core from the end parts of the magnetic circuit loop, the layers of magnetic sheet steel in the end parts of the magnetic circuit loop being arranged with their flat sides facing the window in the core, and the central parts of the winding leg portions of the core loop between the air gaps being positioned with their edges facing the window in the core.

7. The method of making a core structure for an induction device comprising forming a rectangular looped magnetic core having two substantially parallel winding leg portions, by winding a ribbon of thin flat magnetic sheet steel upon itself to form a closed loop about a window to form a magnetic circuit path having a square cross-sectional area, impregnating the spaces between the successive layers of the ribbon of magnetic material with bonding material and baking the core to harden the binding to bond the adjacent layers of said core solidly together, cutting the bonded core loop transversely adjacent each end of each winding leg portion to form two U-shaped core loop yoke parts and two winding leg parts therebetween, assembling the cut parts of the core loop with solid blocks of insulating material between the cut surfaces to space them apart and form air gaps at the joints in the magnetic circuit, and with the winding leg parts turned on their axis after cutting so that the edges of the lamination layers at the cut joints are right angles to the edges of the lamination layers on the opposite sides of the air gaps and the planes of the lamination layers of magnetic sheet steel between the air gaps in each winding leg portion extend across the window surrounded by the core loop, and placing a resilient band of metal under tension about said loop for maintaining a substantially constant pressure on said joints.

8. A magnetic core structure for electrical induction apparatus comprising, in combination, a plurality of laminated yoke portions, each yoke portion being cut from a wound coil, the layers of which are bonded to one another; a plurality of laminated leg portions also cut from a wound coil, the layers of which have been bonded to one another, the leg portions being of substantially the same shape and size in cross section as the yoke portions, the leg portions being disposed between the end faces of the yoke portions, the laminations of the leg portions being disposed to cross at substantially right angles the laminations of the yoke portions; and gaps interposed between the opposed faces of the yokes and legs.

9. A magnetic core structure for induction apparatus comprising, in combination, a plurality of laminated yoke portions, the yoke portions being cut from a wound core, the layers of which are bonded to one another, the ends of the yoke portions having worked faces; a plurality of lam-

inated leg portions, the leg portions being cut from a wound core, the layers of which are bonded to one another, the ends of the legs being worked to provide faces, the worked faces on the yoke portions and leg portions being provided for making butt joints, the leg portions being disposed with their end faces in alignment with the worked faces on the yoke portions, the laminations of the leg portions being disposed to cross at substantially right angles the laminations of the yoke portions; and gaps interposed between the opposed faces of the yokes and leg portions, insulation being disposed in the gaps.

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