Oct. 22, 1940. J. C. GRANFIELD 2,219,182

CORE WINDING ARRANGEMENT

Filed March 8, 1939

Fig. 1.

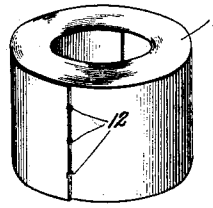


Fig. 2.

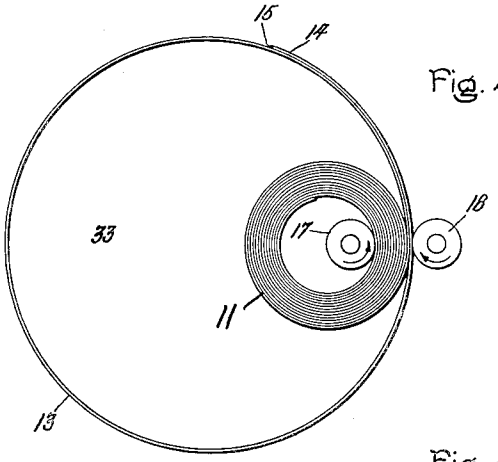


Fig. 3.

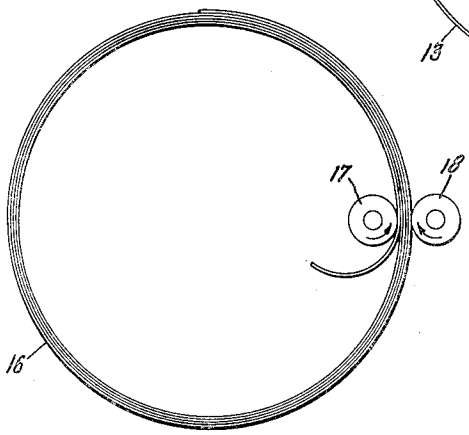


Fig. 4.

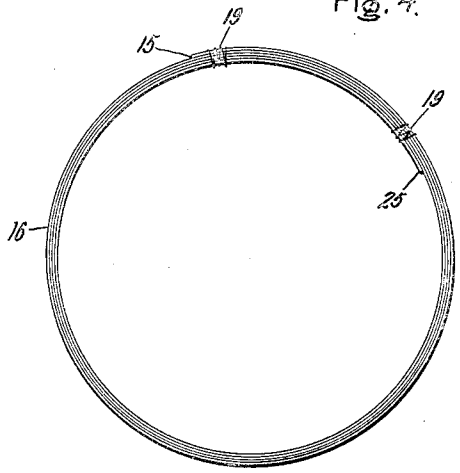


Fig. 5.

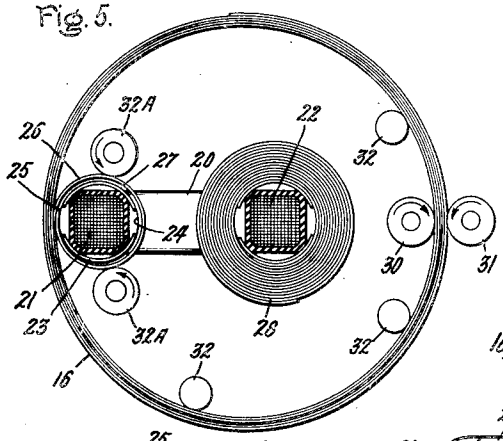


Fig. 8.

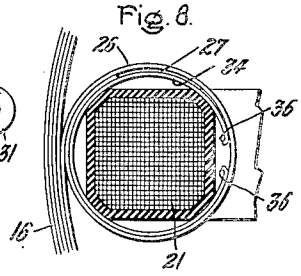


Fig. 9.

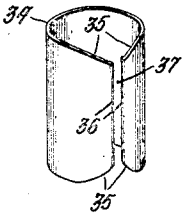
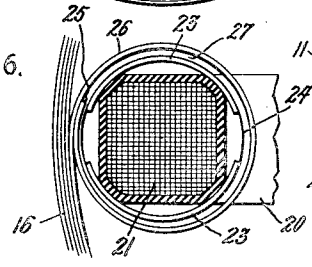


Fig. 6.



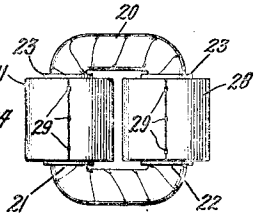


Fig. 7.

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John C. Granfield,
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His Attorney.

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UNITED STATES PATENT OFFICE

2,219,182

CORE WINDING ARRANGEMENT

John C. Granfield, Pittsfield, Mass., assignor to General Electric Company, a corporation of New York

Application March 8, 1939, Serial No. 260,569

5 Claims. (Cl. 29—155.5)

My invention relates to the production of stationary induction apparatus and concerns particularly the application of magnetic core material to electrical windings.

It is an object of my invention to provide a method of assembling wound core stationary induction apparatus and particularly a method of applying magnetic strip material to an electrical winding structure to form a wound core without straining the core material beyond the elastic limit and without leaving the material with any elastic strains, and which method shall be suitable for such materials as three per cent cold-rolled high-reduction silicon steel strip, which requires heat treating and necessitates utilizing the material without having any strains therein in order to obtain the most favorable magnetic properties.

In carrying out my invention in its preferred form I wind a strip of magnetic sheet material of the proper length into a compact hollow cylinder of the same size which a magnetic core is to have in a finished assembled stationary induction apparatus and then subject the material to a suitable heat treatment to bring out its most favorable magnetic properties and to give it permanent set. After the coil has cooled sufficiently I rewind it into a larger coil with the layers of strip forming the turns in the same sequence as in the original coil and without straining the strip material beyond the elastic limit. The large coil is placed around an electrical winding, the inner end of the strip material is looped around the leg of the winding to form the inside of the finished core and the large coil is rotated to cause rotation of the loop and transference of the strip material from the large coil to the outside of the loop. When all of the material has been transferred to the leg of the conductive winding the magnetic coil thus formed is tightened to obtain the same inside and outside diameter as the original coil in the form in which it was annealed.

The invention may be understood more readily from the following detailed description when 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 Figure 1 is a perspective view representing a coiled strip of magnetic sheet material showing its shape and size when annealed and when applied to a finished stationary induction apparatus. Figure 2 is a schematic diagram showing a step in the process of forming the coil of Figure 1 into a coil of larger diameter. Figure 3 is a schematic diagram representing the last part of the step represented in Figure 2. Figure 4 is a diagram showing a large coil of strip material with the layers bound together in a suitable form for shipment or transfer from one part of the factory to another. Figure 5 is a schematic diagram illustrating the process of applying the coil of strip to the electrical winding and showing such an electrical winding in cross section. Figure 6 is a fragmentary enlarged view of a portion of the arrangement of Figure 5 showing in greater detail the leg of the winding to which the strip core is being applied and the portion of the strip in the vicinity of the leg. Figure 7 is a view in elevation showing an assembled stationary induction apparatus such as a transformer or reactor. Figure 8 is a fragmentary view corresponding to Figure 6 showing an arrangement for protecting the conductive winding structure during application of the wound strip core, and Figure 9 is a perspective view of the protective sheath shown in Figure 8.

Magnetic core materials are known which may be so produced as to have relatively low losses and require relatively low magnetizing currents. A material such as high-reduction cold-rolled three per cent silicon steel is of this nature and also permits operation at relatively high flux densities. Such a material, however, cannot be utilized efficiently unless the magnetic flux is caused to pass in the direction of most favorable magnetic properties referred to as the direction of magnetic orientation, and such a material is also very sensitive to mechanical strains either within or beyond the elastic limit. To obtain the most favorable magnetic properties, suitable heat treatment is also required. For the sake of obtaining the advantages of the desirable magnetic properties of such material when the magnetic flux travels along the length of the strip and for the sake of providing highly compact stationary induction apparatus, wound strip magnetic cores are desirable. Since the high-reduction cold-rolled strip material is relatively stiff and springy, it is difficult to handle or to apply to electrical windings. Nevertheless, the greatest insulation efficiency and manufacturing economy of electrical coils and reliability of electrical apparatus generally are obtained when form-wound preformed electrical windings are employed. In carrying out my method of assembling stationary induction apparatus, therefore, I so arrange matters that the core material

may be annealed at proper annealing temperatures before the core material is applied to the winding since annealing temperatures would be destructive of any temperature which could be withstood by insulated electrical windings, and I also arrange matters so that the core material is applied to the winding without straining the material beyond the elastic limit, or leaving it with elastic strains in the assembled structure. The method of doing this, which I invented before making the invention of the present application, is disclosed and claimed broadly in my copending application, Serial No. 123,249, filed January 30, 1937, on which U. S. Patent 2,160,588 was granted May 30, 1939, in which specific arrangements are also disclosed and claimed. The present application discloses a modification of my broader invention.

I first wind a strip of magnetic core material of the proper length into a compact hollow cylinder, as shown in Figure 1, having the inside diameter approximately equal to the outside diameter of the leg of the insulated electrical winding to which the core is to be applied in the assembled stationary induction apparatus. If desired, the strip material may be wound upon an arbor and the outer end of the strip may be secured to the underlying layer of strip material by means of spot welds 12 or by other fastening means to prevent the strip from unwinding during heat treatment. The coil 11 of magnetic material so wound is then placed in a heat treating furnace and is subjected to the proper heat treatment to bring out its favorable magnetic properties and to give it permanent set. This heat treatment, not being my invention and being well understood by those skilled in the art, need not be described herein.

As an intermediate step in applying the strip material to an electrical winding, after the coil 11 has cooled from its heat treatment, it is unwound and rewound into a larger coil 13 as shown in Figure 2. It will be understood that the spot welds 12 are broken in order that the large loop 13 shown in Figure 2 may be formed. Preferably the outer end of the strip 14 is spot welded or otherwise secured to the loop at 15 in order to assist in maintaining the diameter of the loop 13 during the unwinding process. The loop 13 is formed by rolling off the outer layers of the coil 11 and the arrangement is such that the outside layer of the remainder of the coil 11 is successively fed on to the inside of the loop 13 so as to build up a large coil 16 as shown in Figure 3. In transferring the material from the small coil 11 to the large coil 16 care is taken to avoid any sharp bends and to prevent straining the material beyond the elastic limit. It will be observed that the turns of the strip material or the layers forming the turns are in the same sequence in the large coil 16 as in the small coil 11.

For carrying out the unwinding and rewinding process a machine including a pair of rollers 17 and 18 may be employed. One or both, preferably both, of the rollers 17 and 18 are power driven by mechanical connection to a motor not shown, and as indicated by arrows the rollers 17 and 18 are driven in opposite directions of rotation. For the purpose of obtaining better friction, if desired, the rollers 17 and 18 may have tires composed of rubber or other suitable material. Since the total thickness of material between the rollers 17 and 18 decreases as the material is transferred to the larger coil 16, one of the rollers 17 or 18 is provided with a movable mounting resiliently urging it against the other roller to permit the rollers to come closer together and to continue gripping the strip material as the operation proceeds.

Although the rollers 17 and 18 may have their axes either horizontal or vertical, for the sake of convenience in the explanation, it will be assumed that their axes are vertical and that a suitable table is provided for the support of the coils 11 and 16 during the rewinding process.

After the strip material has been fully transferred from the small coil 11 to the larger coil 16, unless the strip is to be applied to a conductive winding immediately, suitable bindings 19 as shown in Figure 4 may be wrapped on the strip to prevent the inner layer of the coil from collapsing. If desired, the process may be carried through to a point represented by Fig. 4 in a steel mill or annealing plant and the large coils may be stored in a warehouse and shipped to a transformer assembling plant when needed.

The manner of applying the magnetic strip material to a conductive winding structure is illustrated in Figure 5, from which it will be seen that the large coil 16 has been placed so as to surround entirely the winding structure 20, having a winding leg 21 on to which the strip material in the coil 16 is to be wound. For obtaining maximum space factor, a winding structure 20 is used, the leg 21 of which is straight. The axis of the large coil 16 is obviously parallel to the winding leg 21. The winding structure 20 may consist of one or more preformed or form-wound electrical conducting windings which have been insulated and have two or more winding legs, one or more of which may be straight winding legs such as the leg 21 and the leg 22, which are intended to have encircling cores of magnetic material. The completed structure may thus form a reactor, a transformer, or in general, stationary induction apparatus. It will be understood that the winding legs 21 and 22 may, if desired, be provided with insulating or protecting sheaths, here represented by partial cylinders composed of tough insulating material, such as heavy paper or fiber, for example, as shown at 23, bound together by means of tape 24 (Fig. 6).

In order to apply the magnetic strip material to the winding leg 21 the end of the inner layer of strip material in the coil 16 is released and allowed to coil around the leg 21 forming a loop 26. The tip end 25 of the strip is secured to the adjacent layer of the coil forming on the loop 20 in any suitable manner as by means of spot welds, clips, or binding tape. In forming the loop 26 and fastening the tip end 25, the inner diameter of the loop 26 is made slightly greater than the extreme diameter of the winding leg 21, for example $\frac{1}{16}$ or $\frac{1}{8}$ inch greater, in order that the loop 26 can coil freely around the winding leg 21 without binding or abrasion of the insulation surrounding the leg 21. The free space 27 between the loop 26 and the insulated winding leg 21 may be observed more clearly in the fragmentary detailed view, Figure 6. The coil 16 is then rotated in such a direction as to cause the material on the inside of the coil 16 to be fed progressively on to the outside of the loop 26 to build up a rotating coil of strip of continuously increasing diameter until all of the strip material has been fed on to the coil surrounding the leg 21. The spot welds or fastening means at the inner tip end of the strip 25

are then broken and the coil is tightened down, so that it acquires the same inside and outside diameters as the original coil 11 in the form of which the strip material was heat treated and the core tightly embraces the winding leg.

In Figure 5 the second winding leg 22 is shown as having already had a coil of magnetic strip or a wound core 28 applied to it in the manner just described. Since the coil 28 has the same inside and outside diameter as it had when annealed, the turns have the same shape and size as when annealed, and the material is free from elastic strain. The material is of course also free from strains beyond the elastic limit, and the most favorable magnetic properties obtainable in the material have been retained. Furthermore, since the coil of material has been unwound from the annealed coil any adhesions between turns which might have been formed during the heat treating or annealing process have been broken up and this source of possible eddy current losses is eliminated. In order to keep the strip material securely in its compact form, spot welds 29 as shown in Figure 7 may be made between the outer end of the strip material and the next adjacent inner layer of strip material.

For the purpose of rotating the coil 16 and transferring the strip material to the loop 26 around the winding leg 21 a machine including a pair of oppositely rotating power-driven rollers 30 and 31 may be employed. It will be understood that the diameter of the coil 16 is preferably made large enough so that not only the entire winding structure 20 but also the roller 30 and a core, such as the core 28 which has already been applied to the winding structure, may be surrounded by the coil 16. As in the arrangement of Figure 5, one or preferably both of the rollers 30 and 31 are power driven by connection to a motor (not shown). They are so arranged that the axis of one of them, preferably the roller 30, is movable transversely and is resiliently urged toward the axis of the other roller. To facilitate rotation of the coil 16 and the loop 26 and to guard against lateral displacement of the coil 16, guide rollers, such as the idling rollers 32 may be provided. With the foregoing procedure the stiffness and springiness of the magnetic strip is no deterrent to the operation since the strip is at times compactly coiled and distributed between only two coils which are tangent and may be securely gripped. For the same reason softer but also sensitive materials such as the nickel-iron alloys may be handled successfully. If desired a pair of power-driven friction rollers 32A, mounted on transversely movable shafts may be utilized to assist in transferring the strip to the loop 26 and later tightening down the coil of strip on the leg 21. In some cases the rollers 30 and 31 may then be dispensed with.

Obviously the same machine and the same power-driven rollers may be utilized for the step in the process represented in Figure 2 and the step represented in Figure 5 by either providing a reversible drive for the rollers or else turning the coil 16 over after it has been formed as explained in connection with Figure 2. In either case the winding structure 20 may be mounted in place in the space 33 to the left of the power-driven rollers 17 and 18 in Figure 2. If desired, the winding structure 20 may be in place in its mounting in the space 33 to the left of the power-driven rollers 17 and 18 while the large coil 16 is being formed. The step of the process represented in Figure 5 may then be carried out either by reversing the direction of drive of the rollers 17 and 18 or by lifting the coil 16 out from between the rollers, turning it over around the horizontal diameter passing through the axes of the rollers 17 and 18, and placing the coil side between the rollers again so as to obtain the same effect as reversal of the direction of rotation of the rollers.

The precise details of construction including the mechanism for supporting and driving the coil-rotating rollers, the supporting table for the strip material, and the arrangement for supporting the conductive winding structure while the strip core is being applied do not constitute a part of my present invention. These details may, if desired, be similar in nature to the corresponding arrangements shown in my copending application, Serial Number 123,250, filed January 30, 1937, on which United States Patent 2,160,589 was granted May 30, 1939, relating to Apparatus for making strip wound magnetic cores and assigned to the same assignee as the present application.

For further protection of the winding structure against abrasion during application of the wound core, I may snap around the winding leg a slit cylindrical sheath of resilient metal which is removable after the core has been transferred to the winding leg. For example, as shown in Figure 8 I may provide a sheath 34 which fits tightly around the winding leg 21 and permits the loop 26 of magnetic strip to rotate loosely around it. If the sheath 34 is utilized the permanent protective sheaths 23 may, if desired, be dispensed with; but, as in the arrangement previously described, the loop 26 is made of sufficient size to provide a free space 27 permitting the loop 26 to revolve around the sheath 34. The removable sheath 34 may be formed as illustrated in Figure 9, consisting of a strip of suitable material such as steel strip bent into a hollow cylinder. The ends of the strip from which the sheath 34 is formed are preferably rounded at the corners 35 and, if desired, the end edges 36 may be rolled in slightly to prevent the sheath 34 from turning on the winding leg 21. If desired, the sheath 34 may be composed of a length of the same type of strip as that utilized for forming the magnetic core. It will be understood that the sheath 34 is bent down to a small enough diameter so that it will tend to grip the winding leg 21. The sheath 34 is snapped on to the winding leg 21 with the slit 37 toward the inside of the conductive winding structure 20 so that when the magnetic strip core has been applied to the winding leg 21 the sheath 34 may be removed by spreading open the slit 37 wide enough to form a gap exceeding the thickness of the conductive winding 29. It will be understood that the sheath 34 is to be removed before the coil of strip forming the core has been allowed to collapse tightly upon the winding leg 21 in order that there will be sufficient space to spread the sheath 34 and open the slit 37 for removal of the sheath 34.

Instead of spot welding or otherwise fastening the end 25 of the strip forming the magnetic core to hold the loop 26 to a sufficiently large diameter, I may also provide an open cylinder-shaped spring piece larger than the diameter of the winding leg on to which the loop 26 may be allowed to collapse and which will hold out the loop 26 to a large enough diameter to allow it to rotate freely around the winding leg 21 while the strip core is being applied. Such a loop-holding spring piece may be of the shape shown in Figure 9, similar to the sheath 34, except, of course, that its diameter is, in this case, made sufficiently

greater so that it can be rotated loosely about the winding leg 21 or about a tight sheath 34 if such a sheath is employed. Furthermore, the rolled-in edges 36 would preferably be omitted in such an open cylinder-shaped spring piece for holding out the loop 26. After all the strip has been transferred to the conductive winding the loop-holding piece is pulled out by spreading it to clear the conductive winding 20 as explained in connection with the description of the sheath 34, and thereafter the strip core is allowed to collapse to the exact diameter of the winding leg 21.

I have herein shown and particularly described certain embodiments of my invention and certain methods of operation embraced therein for the purpose of explaining its principle and showing its application but it will be obvious to those skilled in the art that many modifications and variations are possible and I aim, therefore, to cover all such modifications and variations as fall within the scope of my invention which is defined in the appended claims.

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

1. The method of producing an assembled magnetic core and electrical winding, said method including the steps of winding a strip of magnetic sheet material into a coil in the form of a hollow cylinder, heat treating the coil to improve its magnetic properties and remove strains, unwinding the strip from said coil and simultaneously rewinding it into a larger coil with the layers of strip forming the turns in the same sequence as in the original coil, releasing the inner end of the larger coil while the large coil is entirely surrounding an electrical winding having a leg to which a magnetic core is to be applied parallel to the axis of the larger coil, looping said inner end of the larger coil around the leg of the electrical winding, fastening the tip of said inner end to the adjacent strip material to form a loop sufficiently larger than the leg of the electrical winding to permit relative movement between said loop and the leg of the winding, rotating said larger coil to cause rotation of said loop and to feed the strip material from the inside of said larger coil to the outside of said loop whereby all of the material of the large coil is transferred on to the loop to form a coil of magnetic strip material linking the electrical winding, unfastening the tip of the inner end of the strip material and tightening the coil to the same outside and inside diameter as the original coil of strip material.

2. The method of assembling a magnetic core with an electrical winding having a plurality legs, said method including the steps of winding a strip of magnetic sheet material into a coil, unwinding the strip from the outside of said coil to form a loop of larger diameter than the outside of said coil, successively transferring the outer convolutions from the said coil to the inside of said loop to form a coil of larger diameter, looping the inner end of the strip in said larger coil around a leg of an electrical winding to form a small loop, rotating the large coil around the entire electrical winding to cause said small loop to rotate around the leg of the winding causing the strip material to be transferred from the inside of the large coil to the outside of the small loop around the said leg of said electrical winding thus forming a wound strip core linking the electrical winding.

3. The method of applying a wound strip core to an electrical winding having a plurality of legs which comprises forming the wound strip core material into a coil of sufficient internal diameter to surround entirely an electrical winding to which the core is to be applied, releasing the inner end of the coil of strip, looping it around a leg of the electrical winding forming a loop of greater internal diameter than the diameter of the said leg of the electrical winding, rotating the coil of strip around the entire electrical winding to cause rotation of the said loop around the electrical winding and transference of the strip material from the inside of the coil to the outside of the loop to form a hollow cylindrical core linking the electrical winding, and tightening said strip material to a compact cylindrical core tightly embracing the said leg of the electrical winding.

4. The method of assembling a magnetic core with an electrical winding having a plurality of legs, said method including the steps of winding a strip of magnetic sheet material into a coil of sufficient internal diameter to surround entirely an electrical winding to which the core is to be applied, releasing the inner end of the coil of strip while it is entirely surrounding the electrical winding, having the leg to which the magnetic core is to be applied parallel to the axis of the coil, looping said inner end of the coil around the said leg of the electrical winding, fastening the tip of said inner end to the adjacent strip material to form a loop sufficiently larger than the leg of the electrical winding to permit relative movement between said loop and the leg of the winding, rotating said coil to cause rotation of said loop and to feed the strip material from the inside of the coil to the outside of said loop, whereby all of the material of the coil is transferred onto the loop to form a coil of magnetic strip linking the electrical winding, unfastening the tip of the inner end of the strip material and tightening the coil to a compact core closely embracing the winding leg.

5. A method of assembling a flatwise spirally wound hollow cylindrical coil of magnetic strip around a leg of a conductive winding having a plurality of legs, which method comprises the steps of bringing a relatively large coil of magnetic strip around a plurality of the legs of the said conductive winding structure including said first-mentioned leg, looping the inner end of the large coil around said leg of the conductive winding to form a separate, distinct, relatively small loop of strip having a greater internal diameter than the diameter of the said leg of the electrical winding, and rotating the large coil together with the smaller loop in such a direction as to transfer the strip material from the inside of the large coil to the outside of the smaller loop and thereby form a compact magnetic core surrounding said first-mentioned winding leg.

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