July 15, 1941. P. A. VANCE 2,249,506

STATIONARY INDUCTION APPARATUS

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Fig. 1.

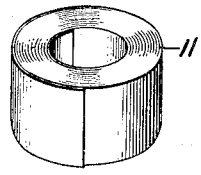


Fig. 2.

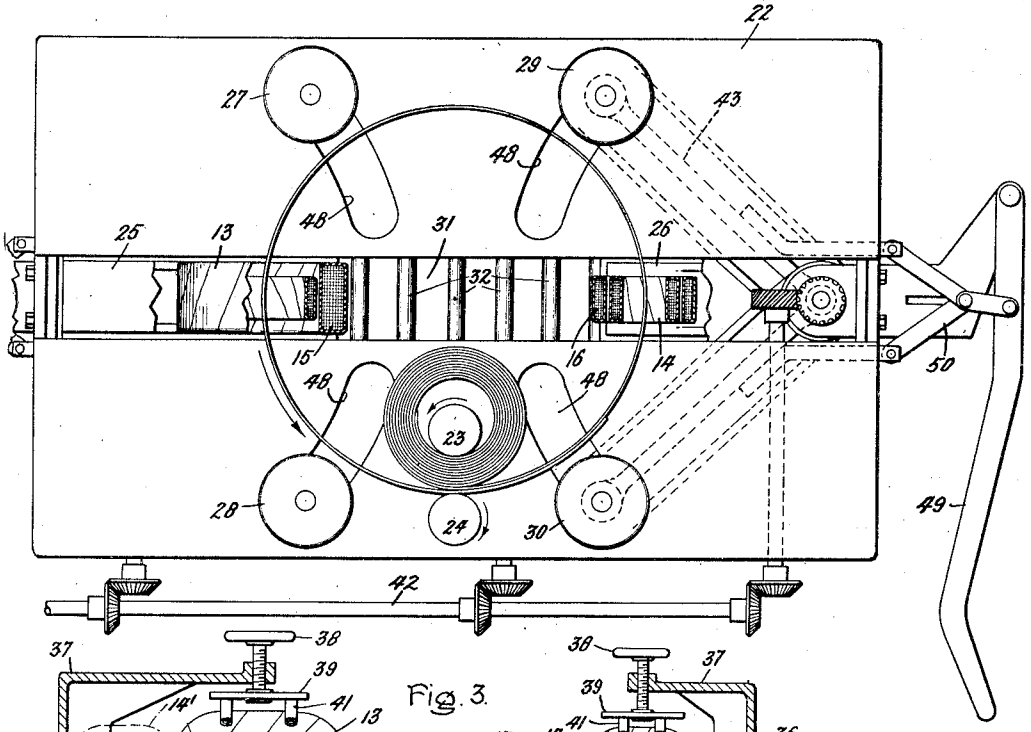


Fig. 3.

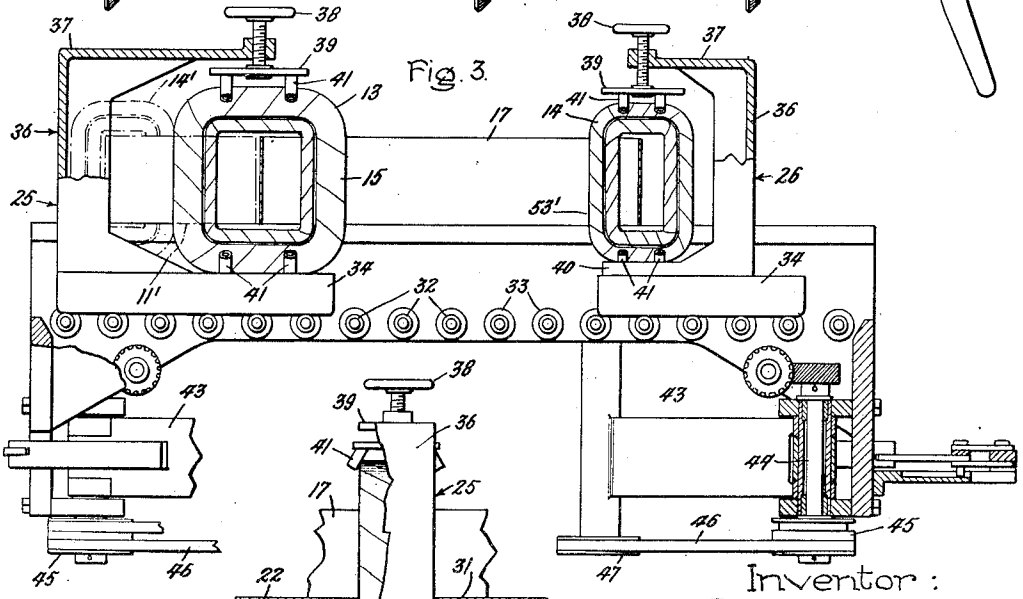


Fig. 4.

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Fig. 5.

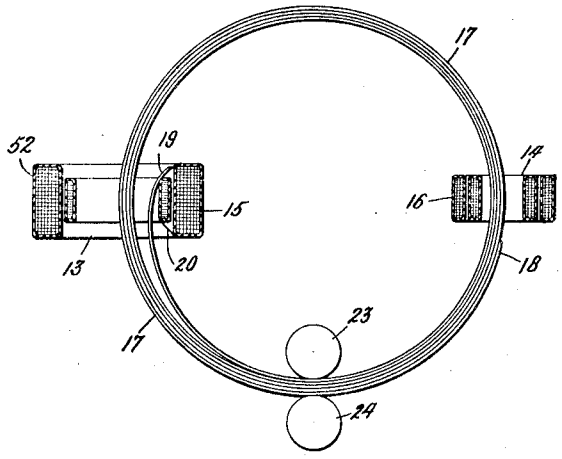


Fig. 8

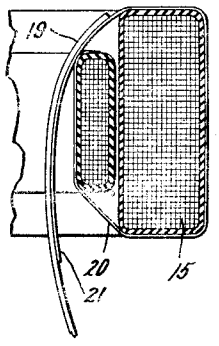


Fig. 6.

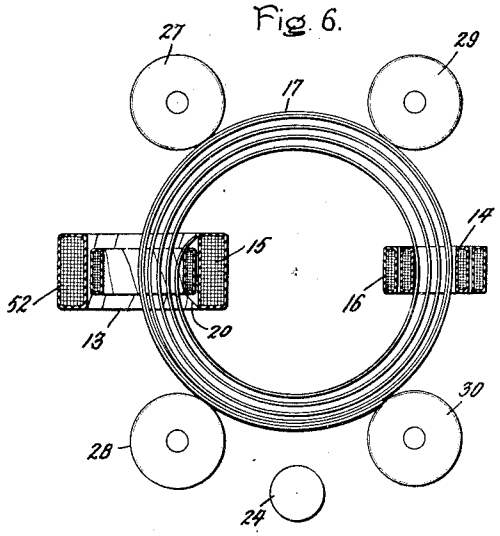


Fig. 7.

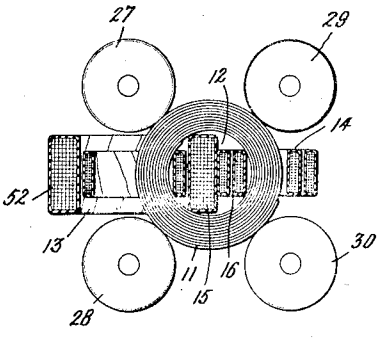


Fig. 9

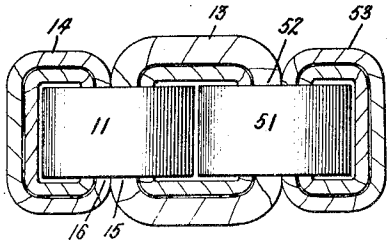
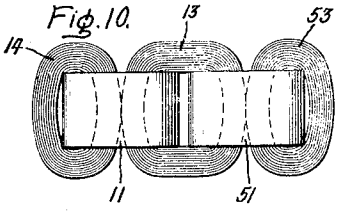


Fig. 10.



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UNITED STATES PATENT OFFICE

2,249,506

STATIONARY INDUCTION APPARATUS

Paul A. Vance, Fort Wayne, Ind., assignor to General Electric Company, a corporation of New York

Application November 30, 1939, Serial No. 306,916

4 Claims. (Cl. 242—4)

This application is a continuation-in-part of my copending application Serial No. 157,758, filed August 6, 1937, and assigned to the same assignee as the present application.

My invention relates to electromagnetic induction apparatus and arrangements for assembling such apparatus. It concerns particularly stationary induction apparatus having two or more winding units and more than one winding leg.

It is an object of my invention to provide improvements in saturable core reactors and three-unit transformers.

It is also an object of my invention to provide methods and apparatus for assembling stationary induction apparatus having wound strip cores with conductive winding structures of the multi-unit type.

Another object is the avoidance of distortion of coils of magnetic strip from true circular shape at any time during assembly with form-wound conductive windings.

Other and further objects and advantages will become apparent as the description proceeds.

My invention may be carried out with conductive-winding structures of the multi-unit type which are separable into two or more units and wound strip cores of the type disclosed in United States Patent 2,160,588 to Granfield. In producing stationary induction apparatus in accordance with my invention in its preferred form, I form a strain-free coil of strip in which the turns have the size and shape which they are to have in a finished magnetic core, I separate the winding units of the conductive winding structure which are to be linked by a common core, and I pass the outer end of the coil of strip through the winding units to form a loop of strip large enough to surround the original coil of strip and the sides of the winding units through which the end of the strip has been passed. The coil of strip and the larger loop are then rotated to transfer the strip material from the coil to the larger loop, whereupon the larger loop is collapsed upon the winding legs and the winding units are simultaneously moved toward each other as the diameter of the larger loop is diminished until the sides of the winding unit surrounded by the loop have been brought together to form a single winding leg and the loop of strip has been reduced to a compact coil closely embracing the winding leg to form induction apparatus in which a common core links the winding units.

The invention may be understood more readily from the following detailed description when considered in connection with the accompanying drawings 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 drawings, Fig. 1 is a perspective view of a coil of magnetic strip before assembly with a conductive winding structure and also showing its form as a finished core. Fig. 2 is a plan view of a machine forming one embodiment of my invention for assembling wound strip cores with multi-unit winding structures. Fig. 3 is an elevation of the apparatus of Fig. 2 shown partially in section. Fig. 4 is a detail end view partially in section of a portion of the apparatus of Figs. 2 and 3. Fig. 5 is a schematic diagram illustrating one of the steps in the operation of assembling a stationary induction apparatus. Fig. 6 is a schematic diagram illustrating another step in the operation. Fig. 7 is a diagram illustrating the final step in the operation of forming a finished core around the conductive winding leg. Fig. 8 is a fragmentary view partially in section illustrating the manner of securing the strip to the winding leg. Fig. 9 is an illustration of a completed three-unit electromagnetic induction device, such as a saturable core reactor or a special alternating-current transformer, and Fig. 10 is an illustration of a saturable core reactor.

In Figs. 7, 9, and 10 there are shown stationary induction devices in which there are one or more annular wound strip cores, such as a core 11 closely surrounding a conductive winding leg 12 of a conductive winding structure including at least two winding units, such as the units 13 and 14, each having a winding side such as the sides 15 and 16 in immediate proximity to form the winding leg 12. Patent 2,160,588 to Granfield, to which reference has already been made, discloses a method of applying wound strip magnetic cores to conductive winding structures which involves unwinding a heat-treated, strain-free coil of strip into a larger loop passing through the conductive winding. It will be seen that in multi-unit conductive winding structures, such as shown in Figs. 7 and 9, it may be difficult to form a larger loop of the requisite size linking the winding units and still retain the loop in circular form. In order to minimize the possibility of straining the magnetic strip beyond the elastic limit, I prefer to assemble the stationary induction apparatus in such a manner that the larger loop need not be distorted from its circular form. Accordingly, I so construct the winding structures that the various non-concentric winding units of which they are composed, e. g., the units 13 and 14, may be separated during the assem-

bling operation, as shown, for example, in Fig. 5. As illustrated in Fig. 2, the winding units 13 and 14 are held a sufficient distance apart to permit passing a loop of strip through them which will surround not only the sides 15 and 16 of the winding units, but also the original coil of strip 11 without causing the larger loop 17 to depart from true circular form.

The coil of strip 11 which has been heat treated, as described in the Granfield patent, to remove deleterious strains and to give the turns of strip a permanent set with the turns in the size and shape which they are to have in the finished core, is held in a suitable position at one side of the winding units 13 and 14. The outer end 18 of the coil of strip is passed through the winding units 13 and 14 back to the coil 11, and fastened to the outside thereof. The coil 11 is then rotated, causing the larger loop 17 likewise to rotate, transferring strip from the outside of the coil 11 to the inside of the loop 17. This rotation is continued until all of the strip material has been transferred to the larger loop 17, whereupon the fastenings of the loop 17 are released and the loop 17 is caused to collapse while the winding units 13 and 14 are being brought together at the same rate as the reduction in diameter of the loop 17. An intermediate stage of this step is shown in Fig. 6, and the final stage is shown in Fig. 7. If the stationary induction apparatus includes more than one wound strip core, the process is then repeated with the additional winding units. For example, three-unit, two-legged, two-core induction apparatus may be formed, as shown in Figs. 9 and 10.

To facilitate the collapsing process and avoid damage of the insulation of the conductive winding structures during the collapsing process, I prefer to secure the inner end 19 of the loop of strip to one of the winding sides. For example, as shown in Fig. 8, a band of suitable material such as insulating tape 20 may be wrapped around the winding side 15 and the inner end 19 of strip may be secured to the band 20 in any suitable manner, as by means of clips or adhesive. If desired, a free end of the tape 21 forming a band 20 may be brought out to facilitate a firm connection with the end 19 of magnetic strip.

In assembling the induction apparatus it is most convenient to have the coils of strip in a horizontal plane with the winding legs vertical or to have the winding units in a horizontal plane with the axis of the coil of strip horizontal, but my invention is not limited specifically to holding the winding units in one plane or the other. In the description of the machine illustrated in Figs. 2 and 3, it is assumed that the conductive winding units are held with their winding legs vertical during assembly with the core strip. The machine illustrated comprises a suitable frame supporting a flat, horizontal table-top 22, a pair of core-strip driving rollers 23 and 24, a driving motor, not shown, movable winding holders 25 and 26 for holding the conductive winding units while the core strip is being applied, collapsing rollers 27, 28, 29, and 30, a suitable track-way for movably supporting the winding holders 25 and 26, and suitable shafting and gearing for communicating rotative force from the motor to the rollers 23, 24 and 27 to 30, inclusive.

The table-top 22 has a lengthwise central opening 31 of sufficient width to admit the winding units. Under the opening 31 the track-way is provided for the winding holders 25 and 26. The track-way is of suitable form to permit the winding holders to travel longitudinally from either end of the table to the center along the opening 31. The nature of the track-way will, of course, depend on the nature of the winding holders 25 and 26. If the latter are provided with flanged wheels the track-way may consist merely of a pair of rails. However, in the machine illustrated, the winding holders 25 and 26 are formed with straight bottoms, and I provide a track-way consisting of a plurality of rotatably mounted rollers 32 placed with their axes parallel and in the same horizontal plane under the opening 31. The rollers 32 may be provided with flanges 33 to maintain the winding holders 25 and 26 centrally positioned with respect to the opening 31.

Each of the winding holders 25 and 26 includes a bed plate 34 in the form of a piece of channel iron with the web portion upwards and the flanged portions 35 downward to bear upon the rollers 33. Secured to the bed plates 34 are clamps 36 having overhanging arms 37 into which adjusting screws 38 may be threaded. Preferably also upper and lower clamping jaws 39 and 40, respectively, are provided which include suitable winding-engaging portions 41 composed of rods or rollers surrounded with soft material, such as rubber, to protect the insulation of the conductive winding units. One or both of the winding holders, for example the winding holder 25, may be made of sufficient size to support a partially completed induction apparatus with one or more cores already applied, as shown in Fig. 3.

The driving rollers 23 and 24 are so mounted that they may grip the side of the strip coil 11 resiliently, one of them for example being carried by a transversely movable support resiliently biased toward the other. For example, the inner roller 23 may be mounted on a transversely movable bearing, one or both rollers being connected by means of suitable gearing to the shaft 42, to which the driving motor is connected. In order that the collapsing operation may be carried out conveniently, roller 23 is removably mounted. Mechanical arrangements for supporting and driving the rollers 23 and 24 are not a part of my invention and are not, therefore, described in detail. The arrangement disclosed in Granfield Patent 2,160,588, and illustrated in Fig. 17 of that patent, may be used.

The collapsing rollers 27 to 30, inclusive, are rotatably supported at the ends of pivoted arms 43. The latter are mounted in pairs on sleeves surrounding countershafts 44 at either end of the frame of the machine. The countershafts 44 are connected by suitable shafts and gearing to the main drive shaft 42 and carry pulleys 45 connected through belts 46 to pulleys 47, each connected by shafts to one of the collapsing rollers 27 to 30, inclusive. In order to permit the collapsing rollers 27 to 30 to be located above the table-top 22 and to have the supporting bearings below the table-top, sector-shaped openings 48 are provided in the table-top 22. For moving the collapsing rollers inward as the larger loop 17 collapses and for maintaining the rollers in contact with the outer layers of the loop 17, means are provided for converging the pairs of pivoted arms 43. For example, a pair of collapsing handles 49 only one of which is shown, may be provided with suitable linkage 50 connected to the arms 43 whereby the arms 43 may be converged by drawing the handles 49 toward the center of the machine. If desired, additional linkage car-

rying projecting arms adapted to engage the winding holders 25 and 26 may be provided for automatically causing the winding holders to be moved towards each other as the larger loop 17 is collapsed in response to movement of the collapsing handles 49.

The operation of the machine is as follows: After the winding units 13 and 14 have been placed in the winding holders 25 and 26 and secured by means of the clamps 38, the coil of strip 11 has been placed over the roller 23, and the outer end 18 of the strip has been separated from the coil, the driving motor is started rotating the drive shaft 22 and the rollers 23 and 24, causing the coil of strip 11 to unwind. As soon as the loop 17 has been formed through the windings 13 and 14 and the end 18 has been fastened to the loop 17, the rotation of the rollers 23 and 24 causes the strip to wind off the coil 11 and into the larger loop 17. After all the strip has been transferred to the larger loop 17, as shown in Fig. 5, and the inner end of the strip 19 has been secured to the winding side 15, the connection at 18 is broken and the inner drive roller 23 is removed, whereupon the collapsing handle 49 is moved inward, the driving motor is restarted, and the friction of the driving rollers on the outside of the strip 17 rotates the larger loop causing it to collapse, as illustrated in Figs. 6 and 7, the winding holders 25 and 26 being pushed together during the process by hand if no connection to the collapsing handle 49 is provided therefor or if the track-way rollers 32 are not arranged to move the winding holders toward each other by gravity or by direct drive. When the strip has been collapsed to the compact core, as shown in Fig. 7, the outer end is preferably fastened to the coil by means of welding or suitable means for the sake of greater security.

In the case of induction apparatus, such as that shown in Fig. 9 or 10, having a second core 51 applied to a different side 52 of the winding 13, the partially completed apparatus shown in Fig. 7 is released from the winding holder 26 and turned around in the winding holder 25 so that the core 11 which has already been applied, and the winding unit 14 which has already been bound to the winding unit 13 by the core 11, occupy the left-hand position, as shown in broken lines in Fig. 3. Thereupon a third winding unit 53 is mounted in the winding holder 26 and the procedure previously described is repeated so that the second core 51 binds the winding unit 53 to the center winding unit 13 forming the completed structure shown in Fig. 9. To avoid confusion the parts 11, 14, and 53 of Fig. 9 are designated in Fig. 3 by the primed numerals 11', 14', and 53', respectively, when in position for application of the second core 51.

Preferably the winding units 13, 14, and 53 are provided with cross sections of such shape that the resultant winding leg 12, as shown in Fig. 7, is substantially cruciform in shape or has a stepped outline in order to obtain the maximum available space factor of the conductor material. It will be understood, of course, that the conductive windings forming the winding structure will be electrically connected in any desired manner to form the desired type of apparatus. For example, in forming saturable core reactors, as in Figs. 9 and 10, the center winding unit 13 is adapted for connection to a source of adjustable direct current for controlling the degree of saturation of the cores 11 and 51 and the winding units 14 and 53 are adapted for connection in series or in parallel in an alternating current circuit in which current is to be controlled by variation of reactance. It will be observed that the construction illustrated forms a compact, sturdy assembly in which the copper and iron coils serve to support and bind each other together. It will also be observed that the conductive winding units 13 and 14 radiate or extend radially from the winding leg 12 so that the mean length of turn of the copper windings and the amount of copper required for a given cross section of magnetic strip is considerably less than would be the case if all the copper windings were wound concentric.

The invention is not, however, limited to reactors and obviously includes also transformers, in which case the winding units having a common core may form primary or secondary windings or, if desired, each of the winding units may be divided into concentric electrical windings as illustrated in the drawings (Fig. 7 and 9) with one of the windings of each winding unit serving as a portion of a primary or secondary winding. In the case of two-unit transformers it will be understood, of course, that the operation is terminated at the step represented in Fig. 7, in which two winding units are bound together by a single core or a group of annular cores in axial alignment simultaneously applied. It will be understood, of course, that if there are to be only two units in the completed stationary induction apparatus, the unit 13 may have its core-receiving opening reduced in size to conserve material.

In accordance with the provisions of the patent 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. A method of assembling a wound strip magnetic core with conductive winding structures including more than one winding unit, which method comprises separating a pair of conductive winding units which are to be linked by a common magnetic core element, separating the end of a wound coil of magnetic strip from the coil, threading the said end through both winding units, securing the end to the outer surface of the coil to form a relatively large loop around sides of both winding units, rotating the coil to unwind it and simultaneously rewind it around the said winding sides into said loop, progressively bringing said winding units closer together and simultaneously collapsing the said loop upon the winding sides until the surrounded winding sides have been brought into proximity to form a winding leg and a core has been formed closely embracing said winding leg.

2. A method of assembling a wound strip magnetic core with conductive winding structures including more than one winding unit, which comprises separating a pair of conductive winding units which are to be linked by a common magnetic core element, passing the end of a coil of magnetic strip through both winding units and around the coil to form a relatively large loop, transferring the magnetic strip material from the coil to the loop and collapsing the loop of magnetic strip while bringing the magnetic winding units towards each other.

3. A machine for assembling magnetic strip

cores with conductive winding structures including more than one winding unit, said machine comprising a track-way, a pair of winding supports adapted to be moved towards each other on said track-way, a pair of rotatable rollers for frictionally engaging and supporting a coil of magnetic strip and a loop of strip crossing the track-way and surrounding the coil of strip, means for driving at least one of said rollers, said rollers being positioned at one side of said track-way, a plurality of collapsing rollers, movable supports and driving means for said collapsing rollers, and means for moving said collapsing rollers inward toward the portion of said track-way opposite the first mentioned pair of rollers in order to engage frictionally a loop of magnetic strip surrounding one of said driving rollers and crossing said track-way.

4. A machine for assembling magnetic strip cores with conductive winding structures including more than one winding unit, said machine comprising means for movably carrying a pair of winding supports, means adjacent thereto for supporting and rotating a coil of magnetic strip and driving a loop from the coil through winding units mounted in said winding supports, and a plurality of power driven collapsing rollers adapted to be moved inward against a loop of magnetic strip to collapse the loop while the winding supports are being moved together.

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