Jan. 15, 1946. F. D. FIELDER ET AL 2,393,037

WINDING SPECIAL CONTINUOUS COIL

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Fig.1.

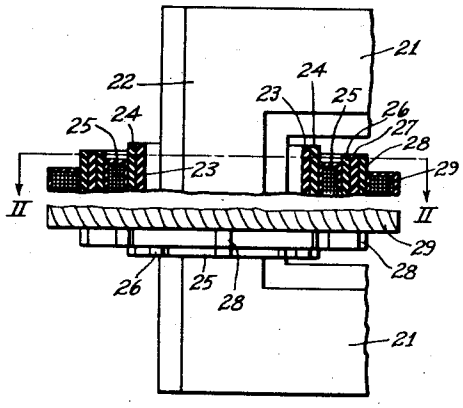


Fig.2.

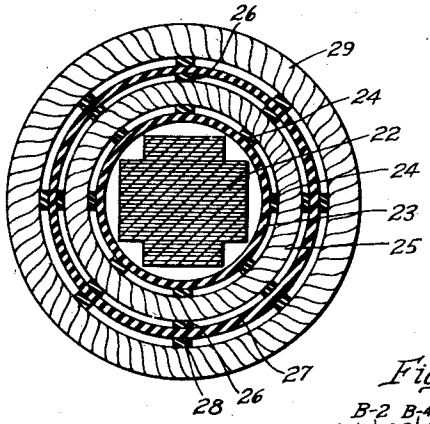


Fig.3.

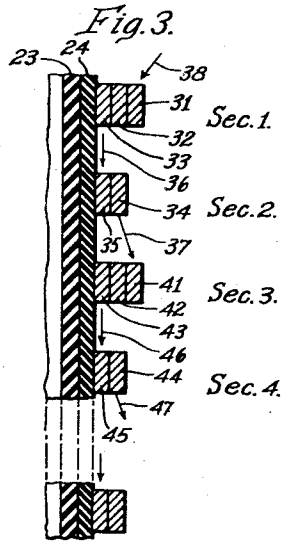


Fig.4.

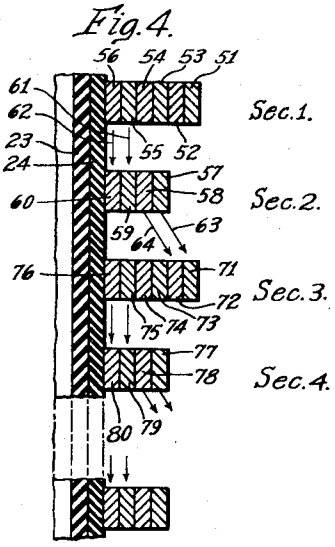


Fig.5.

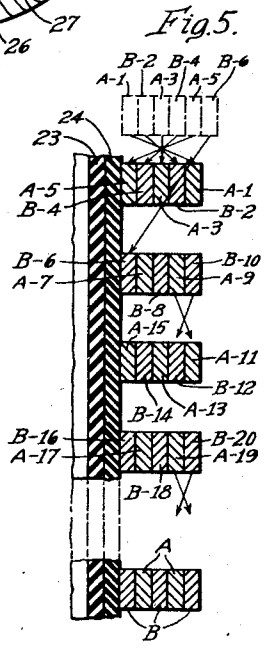


Fig.6.

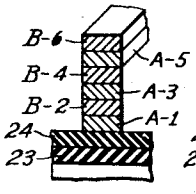


Fig.7.

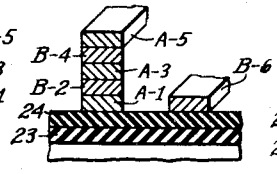


Fig.8.

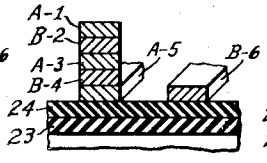
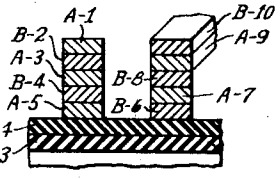


Fig.9.



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Fig. 10.

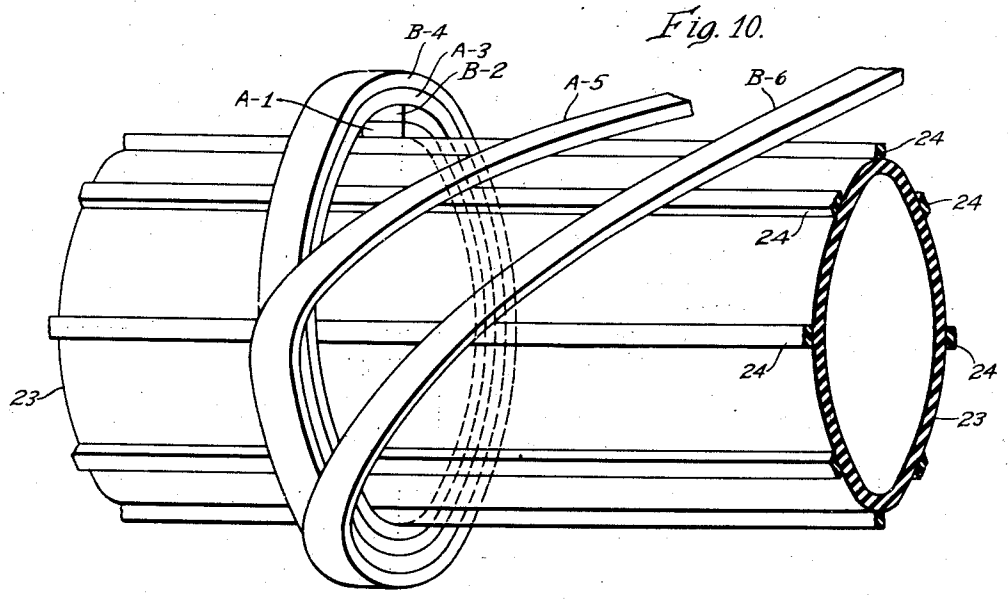
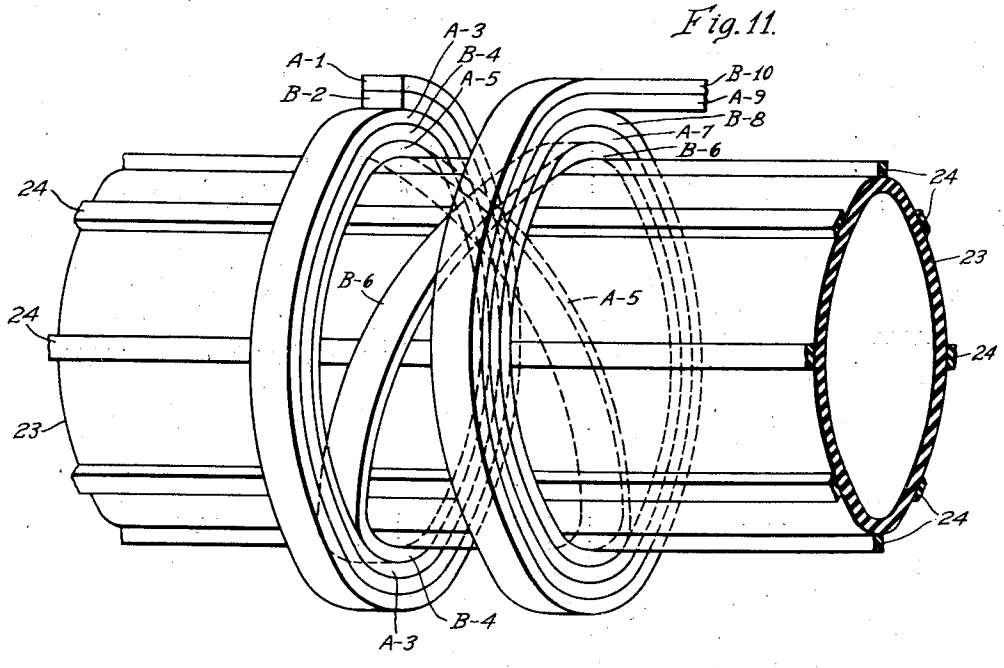


Fig. 11.



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WINDING SPECIAL CONTINUOUS COILS

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Application March 11, 1944, Serial No. 526,082

6 Claims. (Cl. 175—21)

This invention relates to coils for electrical apparatus and to the method of winding coils of the character in which the coil conductor consists of a plurality of conductor strands that are continuous from one end of the winding coil to the other.

In power transformers, particularly in the larger sizes, windings formed of a stack of disc-type or pancake-type coils connected together have been common practice. The continuous type of winding coil, that is, a winding coil in which the several turns of the conductor or of a plurality of conductor strands are continuous from one end of the coil to the other is frequently desirable. However, certain difficulties arise when a relatively few winding turns are required to be distributed along a relatively long cylindrical winding coil. For example, suppose a transformer winding design requires seventy-five turns and suppose that the space requirements work out best with thirty sections to the coil. One way of providing the seventy-five turns in a cylindrical coil having thirty sections would be to use fifteen sections having three turns per section and fifteen sections having two turns per section spaced alternately along the cylindrical support of the coil conductors.

This arrangement gives the proper overall distribution of the winding turns along the winding but is not a good coil electrically, mechanically or economically because of the electrical and mechanical unbalance between the two-turn sections and the three-turn sections of the coil and because of the uneconomical use of the space required for the winding conductor.

It is an object of the invention to provide a continuously wound coil of the above indicated character in which the turns of conductor strands are so divided between a plurality of coil sections that each section contains the same number of full turns of conductor strands.

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 drawings, in which:

Figure 1 is an elevational view of a portion of the core and coil structure of a core-type transformer with parts broken away.

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

Figs. 3 and 4 are sectional views of prior art arrangements of conductors in a cylindrical type coil.

Fig. 5 is a sectional view illustrating an arrangement of the conductor strands of a winding coil organized in accordance with the invention.

Figs. 6, 7, 8 and 9 are views illustrating the method of winding the conductor strands into position as shown in Fig. 5, and

Figs. 10 and 11 are perspective views diagrammatically illustrating the manner in which the conductor strands are wound.

Referring particularly to Figs. 1 and 2 of the drawings, a core 21 is illustrated having a winding leg 22 about which is positioned a tube 23 of insulating material with spacers 24 extending longitudinally of the tube and spaced apart circumferentially about the tube for supporting the inner low-voltage winding 25 of a transformer which is surrounded by vertical spacers 26 of insulating material within a tube 27 of insulating material about which insulating spacers 28 are positioned which support the outer or high-voltage winding 29. It will be appreciated that in the usual form of core-type transformers the core 21 will be rectangular in shape as viewed in Fig. 1 having two winding legs, one only of which is shown. The coil assembly about the winding leg 22 is likewise shown broken in Fig. 1 so that only the end portions of the coil assembly is shown, the top portion of the coil and spacer structure being shown in section and the lower end portion being shown in elevation.

Let us assume that the cylindrical winding coil structure shown in Figs. 3, 4 and 5 are different constructions used to form the low-voltage winding 25 shown in Figs. 1 and 2. If the current required to be carried by the winding conductor is sufficiently small, and if the arrangement of the sections, as in the case assumed above, requires 2½ turns per section, the coil may be wound in the manner shown in Fig. 3, the first section comprising three turns 31, 32 and 33 of the winding conductor; the second section, two turns 34 and 35. The end turn 31 is the winding terminal, the incoming conductor being indicated by the arrow 36. The inner turn 33 of the first winding section is continued directly in series with the inner turn 35 of the second section as indicated by the arrow 36 and the outer turn 34 is connected as shown at 37 to the outer of the three turns 41, 42 and 43 comprising the third winding section. The fourth section comprises two turns 44 and 45, the third and fourth sections being connected as shown by the arrow 46 and the fourth section being connected to the next succeeding section (not shown) by the arrow 47. In this construction every alternate section will consist of three winding-turns and the intermediate alternate sections will consist of two winding-turns.

If the current required to be carried by the conductor is sufficiently high as to require that the conductor be subdivided into two strands or wires wound in parallel, the construction may take the form shown in Fig. 4, which is in general similar to that shown in Fig. 3 except that two strands in Fig. 4 replace the single conductor of Fig. 3. In Fig. 4 the terminal of the winding will consist of the two strands 51 and 52 which, as a pair, are given three turns. The intermediate turns being shown in section at 53 and 54 and the inner turns shown at 55 and 56. The second section of the winding comprises two turns of each of the two strands, the outer turn being shown by strand sections 57 and 58 and the inner turn by strand sections 59 and 60. As shown by the arrows 61 and 62, the inner turn 56 of section 1 is connected directly in series with the inner turn 60 of section 2 and the adjacent strand turn shown as section 55 in section 1 is connected to the strand turn shown as section 59 in section 2. The two outer turns 57 and 58 of the second section of the coil are connected respectively as shown by arrows 63 and 64 to the two outer strand turns 71 and 72 of the third section, which is constructed similarly to the first winding section and comprises two parallel strands having three turns each as indicated at 71, 72, 73, 74, 75 and 76. The fourth winding section comprises the strand turns 77, 78, 79, and 80 arranged similarly to section 2 of the winding. This arrangement of the winding will repeat through every two sections of the winding until the required number of sections are provided.

In the prior art structure shown in Figs. 3 and 4, it will be noted that the space above each of the two-turn sections of the winding is wasted and that the winding is not mechanically strong because of the difficulty in providing proper mechanical support for a winding having the alternate two-turn and three-turn sections. Such a winding is not as good electrically as desired because the transpositions are not completely balanced and also the high-low space (that is, the space between the outer edge of the low voltage winding 25 as shown in Figs. 3 and 4 and the inner edge of the high voltage winding 29) is uneven and somewhat indeterminate.

In accordance with the invention, the winding 25 is improved by arranging the various strand turns in the manner shown in Fig. 5 as will be explained by reference also to Figs. 6 through 11. By comparing Fig. 5 with Fig. 4, it will be noted that one strand of each of the three-turn sections as shown in Fig. 4 has been taken away from that section and placed in the next section so that there will be five strand turns per section rather than six strand turns in alternate sections and four strand turns in the intermediate alternate sections.

Perhaps the relative position of the strands may be most easily explained by referring to the method of winding the coil. The insulating tube 23 with the spacers 24 in place is rotated in a winding machine for that purpose until three conductor turns of the two conductor strands have been wound into position as shown in Fig. 6 and in the dotted lines in Fig. 5. The separate strands are identified throughout by the letter A or B, the six strand sections shown in Figs. 5 to 9 being identified respectively as A—1, B—2, A—3, B—4, A—5 and B—6 representing six strand turns as shown in section. The three turns of the strand A are identified in Fig. 6 as A—1, A—3 and A—5 and the three turns of the strand B are identified as B—2, B—4 and B—6.

The next step is to move the top strand B—6 to one side as shown in Fig. 7. The first five strands are then rewound by hand, reversing the order of the strands as shown in Fig. 8 and in Fig. 5, the strand A—5 being the inner strand and the strand A—1 being the outer strand of the first section in its completed form. Referring to Fig. 5, the temporary section is shown in dotted lines and the permanent positions of the six strands are shown in hatched areas connected by arrows to the corresponding rectangles shown in the dotted outlined temporary section. For example, the strand B—6 is moved from the outer position of the temporary position to the inner position of the second winding section and the remaining five strands A—5 to A—1 are reversed radially to bring the turns A—1 and B—2 which are the inner turns in temporary section to the outer periphery of completed section 1.

The second section of the winding is completed by machine winding two turns of the two-strand conductor upon the strand B—6. As shown in Fig. 9 and in the completed second section in Fig. 5, the strand A is shown as through the positions A—7 and A—9 and the strand B is shown as continuing through the positions B—8 and B—10. It will be noted by reference to Figs. 9 and 5 that there are three full turns of strand A in section 1 of the winding and two turns of strand B, while in the second section of the winding there are three turns of the strand B and two turns of the strand A. This winding procedure is continued throughout the winding, the sequence of the conductor strands repeating in successive pairs of sections, the conductor strands in section 3 being arranged in a similar manner to those in section 1 and the strands in section 4 being arranged in a similar manner to those in section 2, and so on throughout the length of the winding. The strands A—11, B—12, A—13, B—14 and A—15 in section 3 are positioned respectively, similarly to strands A—1, B—2, A—3, B—4 and A—5 of section 1 of the winding, and the strands B—16, A—17, B—18, A—19 and B—20 in section 4 of the winding are positioned respectively similarly to the strands B—6, A—7, B—8, A—9 and B—10 in section 2 of the winding.

This arrangement of the strands is effected for each pair of sections of the winding in the same manner as for the first pair. That is to say, a temporary third section is wound having strand turns A—11, B—12, A—13, B—14, A—15, and B—16 arranged in the same sequence as strands A—1, B—2, A—3, B—4, A—5 and B—6 in the first temporary disc-type section, and then rewound to reverse radially the positions of the strands of the third temporary disc-type section to form the third section in the same manner as the first completed section was formed from the first temporary section. The fifth, seventh, ninth, etc. sections are similarly formed.

Fig. 10 illustrates somewhat diagrammatically the arrangement of the conductor strands as shown in Fig. 7. The first winding turn comprises the strands A—1 and B—2 and the second winding turn is indicated by strands A—3 and B—4. In Fig. 10 the outer positions of the strands A and B, indicated respectively as A—5 and B—6, are shown as they are moved toward the positions shown in Fig. 8 in which the strand B—6 becomes the inner strand of the second winding section and the strand A—5 becomes the inner strand of the completed first section.

Referring to Fig. 11, the strands A—1, B—2, A—3, B—4 and A—5 are shown in their final positions corresponding to that shown in Figs. 8, 9 and 5, the strand A being continued from the position A—5 in the first section to the position of A—7 in the second winding section to be positioned about the strand B as indicated in position B—6 which is a continuation of the strand B from the position indicated as turn B—4 in the first winding section. In this transposition it will be noted that the strand B continues from position B—4 surrounding the strand A in position A—5 to position B—6 in section 2 so that in section 2 of the winding the strand A surrounds the strand B whereas in section 1 the strand B surrounds the strand A. By thus reversing the position of the two strands radially between the two winding sections, the strand A occupies both the outer position and the inner position in section 1 of the winding and the strand B occupies both the inner and outer positions in section 2 of the winding. The dimensions shown in Figs. 10 and 11 and the sweep of the conductor strands in being transposed from one section to another of the winding is largely diagrammatic and is not to scale in order that the character of the transpositions made may be more clearly indicated in the drawings.

For purposes of illustration, a winding comprising say seventy-five turns arranged in thirty sections having 2½ turns per section and formed of a conductor comprising two parallel strands has been illustrated. The principle involved can be applied to any winding, or portion of a winding, of the character illustrated having an even number of winding sections, an odd number of conductor turns per pair of sections, and any even number of strands per conductor.

Modifications in the structure and arrangement of parts illustrated and described may be made within the spirit of our invention, and we do not wish to be limited otherwise than by the scope of the appended claims.

We claim as our invention:

1. An electrical winding coil formed from a continuous winding conductor having a plurality of parallel conductor strands, the winding coil comprising a plurality of coil sections of such number that a fractional number of winding turns per coil section is required, the strands of each conductor being arranged in full turns in each section, the full turns of conductor strands being so distributed among the several coil sections as to provide a different number of turns of each strand in a given section than in other sections while providing the same number of full turn conductor strands in each section to provide the equivalent of a fractional conductor turn in each coil section.

2. An electrical winding coil formed from a continuous winding conductor having a plurality of parallel conductor strands, the winding coil comprising a plurality of coil sections of such number that a fractional number of winding turns per coil sections is required, said parallel conductor strands being arranged to provide the same number of full turns of conductor strands in each coil section of the winding by providing a greater number of turns of one conductor strands in a given coil section than the number of the remaining conductor strands in that section and in providing a greater number of turns of another strand in an adjacent coil section of the winding than the number of turns of the remaining coil strands in that section.

3. An electrical winding coil formed from a continuous winding conductor comprising a pair of parallel conductor strands, the winding coil comprising a plurality of coil sections, the number of winding turns required for the coil being such that the turns per section of the winding coil includes a number of full turns plus a half turn, the two parallel strands of said conductor being arranged with a given number of full turns of both of the two strands in each coil section plus a full turn of one only of the two strands in a given section and a full turn of the other one only of the two strands in the next adjacent section of the coil, this sequence being repeated throughout the coil winding.

4. In an electrical apparatus, a winding tube, a winding coil positioned about the winding tube, the coil being formed from a continuous winding conductor comprising a plurality of conductor strands arranged in a plurality of disc-type coil sections spaced along the winding tube in which the several conductor strands extend radially within the group of strands forming the conductor, all conductor strands being positioned about the winding tube in a given section radially in a given sequence for a given number of full turns and less than all of the strands being given an additional full turn in that section, the remaining conductor strands being given a full turn adjacent the winding tube in the space provided for the next section of the winding coil, all conductor strands being positioned about the first full turn of strands to provide a total number of full turns of conductor strands in the second section corresponding to the total number of full turns of conductor strands in the first defined section, the above defined sequence of conductor strands in the coil sections being repeated throughout successive pairs of sections of the winding coil.

5. The method of winding an electrical coil from a conductor comprising a plurality of conductor strands which consists of winding a number of complete full turns of all strands to form a first temporary disc-type section of the coil with the several strands positioned radially in the conductor, taking the outer strand from the first temporary disc-type section to a position as the inner strand of a second disc-type section, rewinding the first temporary disc-type section to reverse radially the positions of the strands of the first temporary disc-type section to final position thereby to form the completed first section, winding a given number of full winding turns of the several conductor strands comprising the conductor over the first strand of the second winding section, and in repeating the above defined operation to produce a winding coil comprising a plurality of disc-type winding coil sections in which the number of full turns of conductor strands per section is unlike for all strands comprising the conductor.

6. The method of winding an electrical coil from a conductor comprising an even number of conductor strands which consists of winding a number of complete full turns of all strands of the conductor to form a first temporary disc-type section of the coil with the several strands positioned radially in the conductor, taking the outer half of the conductor strands from the first temporary disc-type section to a position as the inner strands of a second disc-type section, rewinding the first temporary section to reverse radially the positions of the strands of the first temporary disc-type section to final position thereby to form

the completed first section, winding a given number of full winding turns of the several conductor strands comprising the conductor over the already positioned strands of the second winding section, and in repeating the above defined operation to produce a winding coil comprising a plurality of disc-type winding coil sections in which the number of full turns of conductor strands per section includes a given number of all conductor strands plus a full turn of one half the conductor strands comprising the conductor.

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