Nov. 9, 1948. G. F. STEARN 2,453,552

TRANSFORMER WINDING

Filed Jan. 2, 1946 4 Sheets-Sheet 1

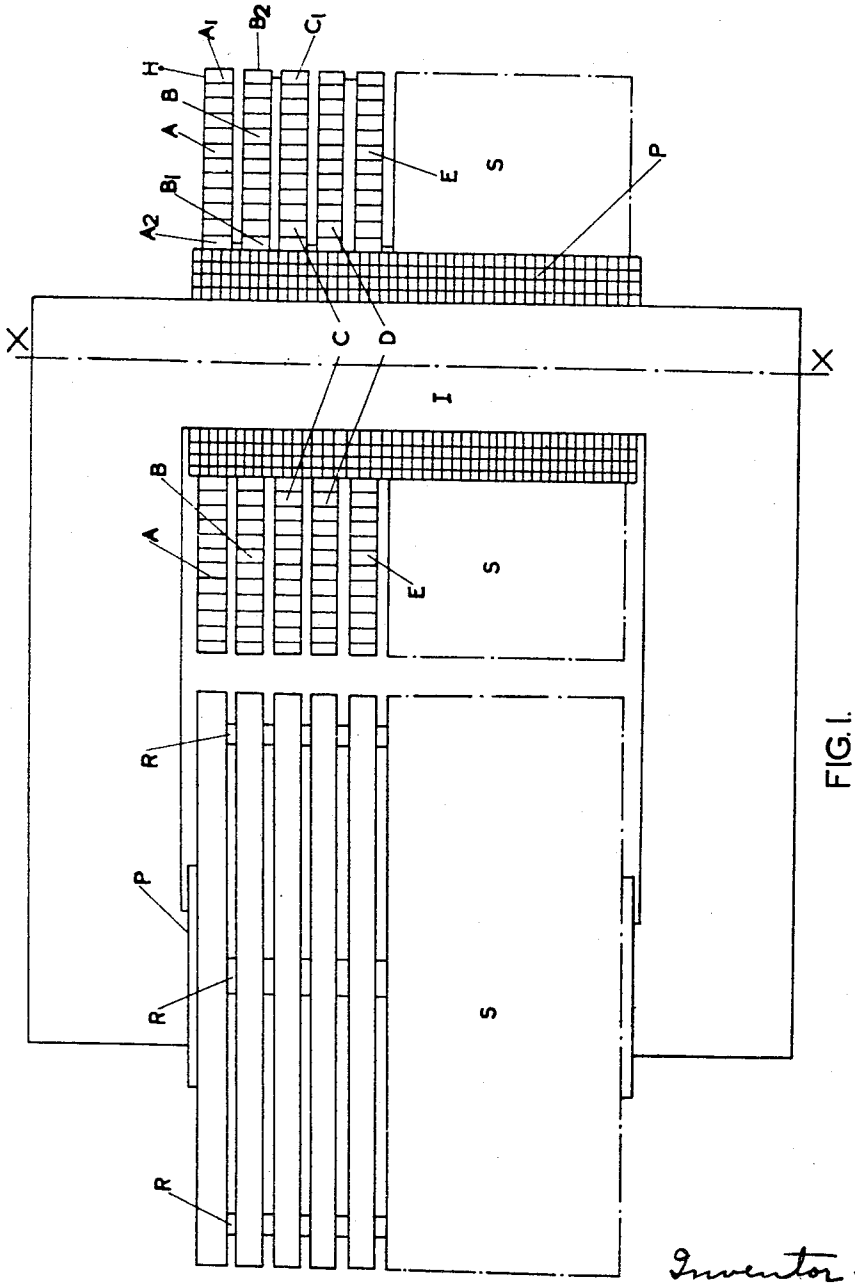


FIG. I.

Inventor:
George F. Stearn
by Babcock & Babcock
Attorneys

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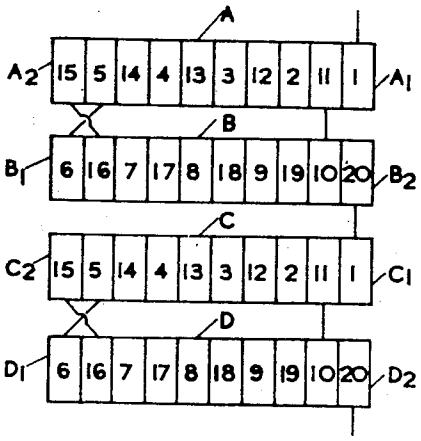


FIG. 2.

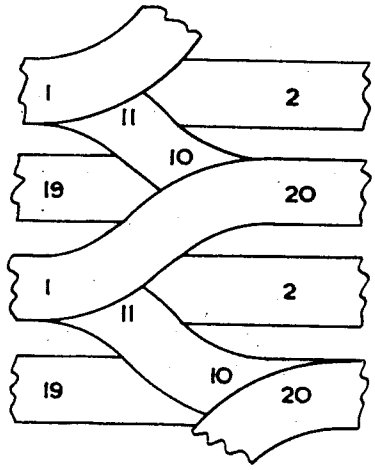


FIG. 2A.

Inventor
George F. Stearn
by Babcock & Babcock
Attorneys

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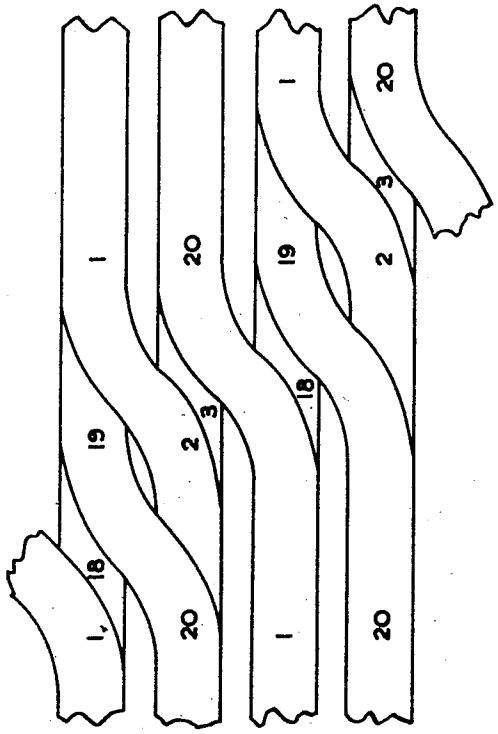


FIG. 3A.

FIG. 3.

Inventor
George F. Stearn
by Babcock & Babcock
attorneys

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TRANSFORMER WINDING

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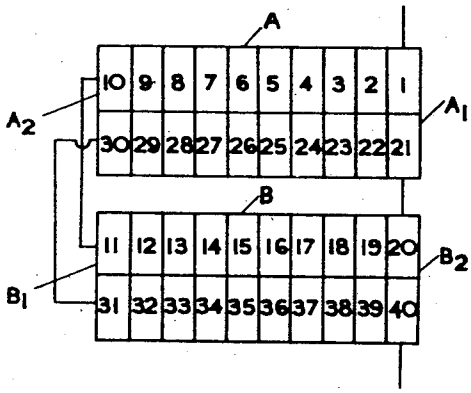


FIG. 4.

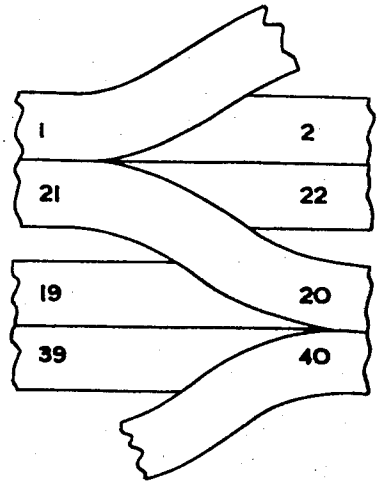


FIG. 4A.

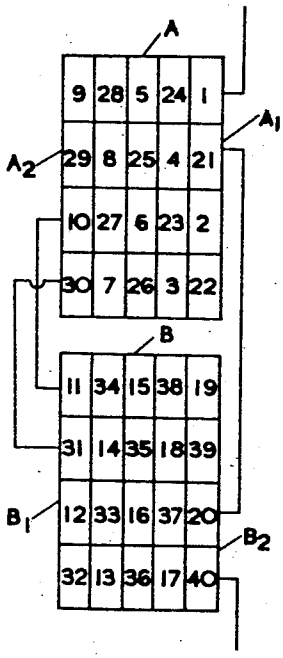


FIG. 5.

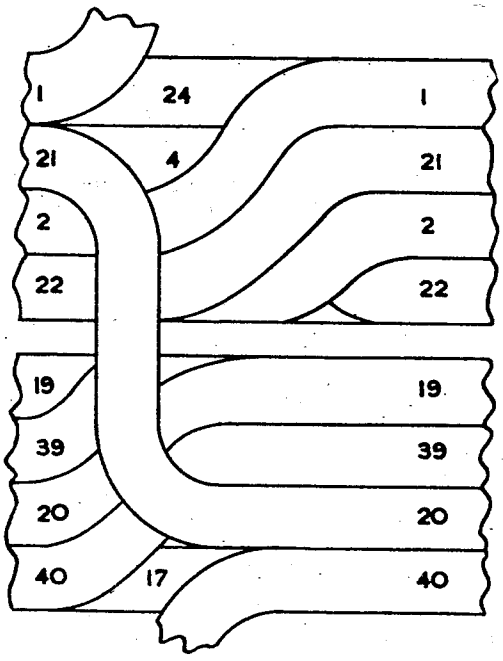


FIG. 5A.

Inventor
George F. Stearn
by Babcock & Babcock
Attorneys

Patented Nov. 9, 1948

2,453,552

UNITED STATES PATENT OFFICE

2,453,552

TRANSFORMER WINDING

George Fletcher Stearn, Stafford, England, assignor to The English Electric Company Limited, London, England, a British company

Application January 2, 1946, Serial No. 638,660
In Great Britain January 4, 1945

6 Claims. (Cl. 175—362)

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This invention is concerned with the avoidance of difficulties of insulation against abnormal voltage distributions in electrical inductance windings such as the windings of chokes and transformers.

The invention may be applied only near the high potential end of a winding, or it may be applied in other parts also. The term "winding" will hereafter be used to mean any part of a winding to which the invention is applied.

The invention is applied in a winding which is divided into a plurality of annular sections each of which comprises one or more spiral conductors, these sections being spaced apart along a common axis. The conductors in some sections spiral outwards while those of other sections spiral inwards for the same direction of turn around the common axis. If any one section, however, comprises more than one spiral conductor, then in that section they all spiral inwards or all outwards. The turns of any one spiral may all be superposed in a single radial layer, but alternatively in any section comprising more than one spiral conductor they may be interchanged axially once or more than once in the course of winding.

The term "coil" will be used herein to mean two spiral conductors, one spiralling outward and one inward, connected in series with each other. These are necessarily in different sections, because they spiral oppositely. The winding is made up of a plurality of coils in series.

In a winding according to the principal feature of the invention, one of the first few turns of every coil is placed in the same section as, and immediately beside, one of the last few turns of the same coil or one of the first few turns of the next coil, so as to provide a high capacitance path in parallel with at least the greater part of every coil.

The provision of such high capacitance paths leads to more uniform potential distribution through the winding when a potential variation of steep wave front is applied; and it also reduces the amplitude of subsequent oscillations which are produced in the winding under this condition.

In the accompanying drawings, Fig. 1 is a part sectional elevation of the core and windings of a transformer of the kind in which the invention can be applied, Fig. 2 is a diagram illustrating one arrangement of winding in accordance with the invention and Fig. 2*a* is a diagram illustrating the arrangement of the connections at the outside of the winding represented by Fig. 2. Figs. 3, 4, and 5 are diagrams similar to Fig. 2 but

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each representing a different arrangement of winding according to the invention, and Figs. 3*a*, 4*a*, and 5*a*, are diagrams corresponding to Fig. 2*a* and showing the arrangement of the connections at the outsides of the windings represented by the corresponding Figs. 3, 4, and 5.

The transformer shown in Fig. 1 is a single phase core type transformer having similar windings on the two limbs of the core I. On each limb there is a winding P of layer type surrounded by a winding S which is a winding of the kind to which the invention can be applied. Parts of the transformer which are not necessary to an understanding of the invention are omitted from Fig. 1 for the sake of clarity.

The winding S in Fig. 1 is made up of a considerable number of annular sections A, B, C, etc. which are spaced apart along a common axis X—X which is the axis of the limb of the score I around which this winding is mounted. The sections A, B, C, etc. are spaced apart in the usual manner by radial strips R; and cooling fluid is enabled to flow between the sections in the spaces between these strips R.

Each of the sections A, B, C, etc. is made up of one or more conductors spirally wound about the axis X—X. For the same direction of turn around the axis the windings of successive sections spiral alternately inwards and outwards. The high potential terminal H of the winding is connected to the outside turn A_1 of section A and the winding of this section spirals inwards. The last turn A_2 which is therefore at the inside, is connected to the first turn B_1 of section B which is wound spirally outwards. The last turn B_2 of section B, which is at the outside, is connected to the first turn C_1 of section C. This section is wound spirally inwards. The connections continue in the same manner throughout the winding.

Fig. 2 shows diagrammatically the arrangement and connections of the conductors making up the first four sections A, B, C, D, of a preferred winding according to the invention. The turns on the right represent the outside turns A_1, B_2, C_1, etc. and the turns on the left represent the inside turns A_2, B_1, C_2, etc.

In the arrangement shown in Fig. 2, each section comprises two spiral conductors which are superposed in a single radial layer. The turns 1, 2, 3, 4, 5, represent the turns of one of these conductors in section A; and the turns 11, 12, 13, 14, 15, represent the turns of the other conductor in this same section A. The turns of the second conductor lie between the turns of the first con-

ductor and similarly the turns of the first conductor lie between the turns of the second conductor. Section B similarly comprises two spiral conductors superposed in a single radial layer; but in this section the winding spirals outward. Section C is similar to section A and section D is similar to section B.

Turn 10 in section B, which is the outside turn of one of the conductors in section B, is directly connected to turn 11 in section A, which is the outside turn of one of the conductors in section A. Turn 5 in section A, which is the inside turn of one of the conductors in section A, is connected to turn 6 in section B which is the inside turn of one of the conductors in section B. Turn 15, which is the inside turn of the other conductor in section A, is connected to turn 16, which is the inside turn of the other conductor in section B. The last turn 20 of this conductor in section B is connected to the first turn 1 of one of the conductors in section C.

The first coil of this winding, in the sense in which the term "coil" is used in this specification, is made up of the turns 1 to 5 in section A, which spiral inwards, and the turns 6 to 10 in section B, which spiral outwards, connected in series with each other. The second coil consists of turns 11 to 15 in section A, which spiral inwards, connected in series with turns 16 to 20 in section B, which spiral outwards.

With this arrangement, the first turns 1 and 2 of the first coil are placed in the same section A as, and immediately beside, the first turn 11 of the second coil. The last turn 10 of the first coil is placed in the same section B as, and immediately beside, the last two turns 19 and 20 of the second coil. The high capacitances between turn 11 and each of turns 1 and 2 provide paths of high capacitance in parallel with the first coil. Similar paths are provided by the capacitances between turn 10 and each of turns 19 and 20 in parallel with the next coil; and by the capacitances between turn 11 and each of turns 1 and 2 in section C, and so on.

Thus high capacitance paths are provided in parallel with each coil of the winding by placing the first turn 1 in section A, at the high potential end of the winding, immediately beside turn 11 which is directly connected to a turn 10 in another section B; this turn 10 itself being placed immediately beside a turn 20 which is directly connected to a turn 1 in another section C; and this continues throughout the winding, or throughout that part of the winding to which the invention is applied.

The arrangement of the connections at the outside of the winding are seen in Fig. 2*a*. Any of these connections may be made by carrying on a continuous conductor or by joining the ends of two separate conductors.

In the alternative arrangement shown in Fig. 3, each section comprises only a single spirally wound conductor, with the exception that the outside turns of the two sections are exchanged with each other. The necessary arrangement of the connections at the outside of the winding to effect this exchange is illustrated in Fig. 3*a*. Sections A and B now provide only a single coil. There are high capacitance paths between the first turn 1 and the penultimate turn 19 and again between the second turn 2 and the last turn 20. Each of these high capacitance paths is in parallel with the greater part of the coil.

In the arrangement shown in Fig. 4, each of the sections comprises two spirally wound conductors,

but these are placed side by side axially instead of radially so that the turns of one are not superposed upon and do not lie between the turns of the other. The conductors usually have an axial width greater than their radial thickness and therefore this arrangement does not provide such high capacitance paths as are obtainable with the arrangement shown in Fig. 2. Nevertheless the capacitance is considerable and appreciable benefit may be obtained from this arrangement.

In the arrangement shown in Fig. 5, each section is spirally wound with two conductors placed axially beside each other but these are wound so that each conductor provides two turns in each axial layer of the section; and the two conductors are crossed over in passing from each layer to the next within the section. The first coil is made up of turns 1 to 10 in section A in series with turns 11 to 20 in section B. The second coil is made up of turns 21 to 30 in section A in series with turns 31 to 40 in section B. Turn 1 has a high capacitance to turns 21 and 24. Turn 2 has high capacitance to turns 21, 22 and 23.

In the arrangement shown in Fig. 3, high capacitance paths in parallel with the coils are provided only by the outer few turns of each coil. The arrangements shown in Figs. 2, 4, and 5 have the advantage that every turn throughout that part of the winding to which the invention is applied is placed immediately beside a turn which is connected considerably further on in the winding. This may necessitate increased insulation, but it also serves to provide a very large number of high capacitance paths throughout the winding which are of assistance in achieving a more uniform potential distribution throughout the winding when a potential variation of steep wave front is applied.

What I claim as my invention and desire to secure by Letters Patent is:

1. An inductive winding having a portion at its high potential end arranged in a pair of annular sections spaced apart along a common axis and having cross-connections between them, one of the sections containing at least one conductor which consists of a plurality of turns spiralling inwards and the other of the sections containing at least one conductor which consists of a plurality of turns spiralling outwards, characterized in that there is a conductive path from a starting turn near the outside edge of one section to a finishing turn near the outside edge of the other section, this conductive path comprising, in the order named, from the starting turn an inward spiral in one section, an inner cross-connection, an outward spiral in the other section, an outer cross-connection, a second inward spiral in the first-named section, a second inner cross-connection, and a second outward spiral in the second-named section to the finishing turn, and further characterized in that there is a capacitive by-path from said starting turn to said finishing turn comprising in the order named, the capacitive coupling between the starting turn and the first turn of the second inward spiral, said outer cross-connection, and the capacitive coupling between the last turn of the first outward spiral and the finishing turn.

2. An inductive winding according to claim 1, characterized in that the turns of the two inward spirals are superposed and interleaved in a single radial layer, and similarly the turns of the two outward spirals are superposed and interleaved in a single radial layer.

3. An inductive winding having a portion at

its high potential end arranged in a pair of annular sections spaced apart along a common axis and having cross-connections between them, one of the sections containing at least one conductor which consists of a plurality of turns spiralling inwards and the other of the sections containing at least one conductor which consists of a plurality of turns spiralling outwards, characterized in that there is a conductive path from a starting turn near the outside edge of one section to a finishing turn near the outside edge of the other section, this conductive path comprising in the order named, the starting turn in one section, an outer cross-connection, an inward spiral in the other section, an inner cross-connection, an outward spiral in the first-named section, a second outer cross-connection, and the finishing turn in the second-named section, and further characterized in that there are two capacitive by-paths in parallel with each other from said starting turn to said finishing turn, one of said by-paths consisting of the capacitive coupling between said starting turn and the last turn of said outward spiral in the first-named section, and of said second outer cross-connection to the finishing turn, and the other of said by-paths consisting of the first said outer cross-connection from the starting turn and the capacitive coupling between the first turn of said inward spiral in the second section and said finishing turn.

4. An inductive winding having a high potential end portion comprising a pair of annular sections each containing a plurality of conductor turns and comprising a plurality of cross-connections between said sections, at least some of the conductor turns in one section forming at least one inward spiral, and at least some of the conductor turns in the other section forming at least one outward spiral, and wherein a conductive path is provided from the outermost turn of one section to the outermost turn of the other section, said conductive path being wholly within said pair of sections and said cross-connections, and passing through at least one inward spiral, at least one inner cross-connection between an inward and an outward spiral, at least one outward spiral, and at least one outer cross-connection between the second outermost turn of one of said sections and one of the two outermost turns of the other of said sections, and wherein a capacitive by-path is provided through said outer cross-connection and through at least one of the capacitances between the outermost turns and the second outermost turns of said sections.

5. An inductive winding having a high potential end portion comprising a pair of annular sections spaced apart along a common axis, one of said sections comprising a plurality of conductors spiralling inward and having the first turn of a first conductor in close capacitive coupling with an adjacent first turn of another conductor, the other of said sections comprising a plurality of conductors spirally outward and having the last turn of a last conductor in close capacitive coupling with an adjacent last turn of another conductor, and having a conductive path from said first turn of said first conductor to said last turn of said last conductor, said conductive path passing in series through a plurality of conductors selected alternately from said two sections, and having a direct conductive path from said adjacent first turn to said adjacent last turn.

6. An inductive winding having a high potential end portion comprising a pair of annular sections spaced axially apart, a conductor spiralling outwardly in a first of said sections, but having its last turn transposed into the second of said sections, a conductor spiralling inwardly in the second of said sections, but having its first turn transposed into the first of said sections, having a conductive path from said first turn to said last turn, said conductive path passing through said conductors in series, and having capacitive paths from said first turn to said last turn through the capacitive couplings between the transposed turns and the adjacent turns in the sections into which they have been transposed.

GEORGE FLETCHER STEARN.

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