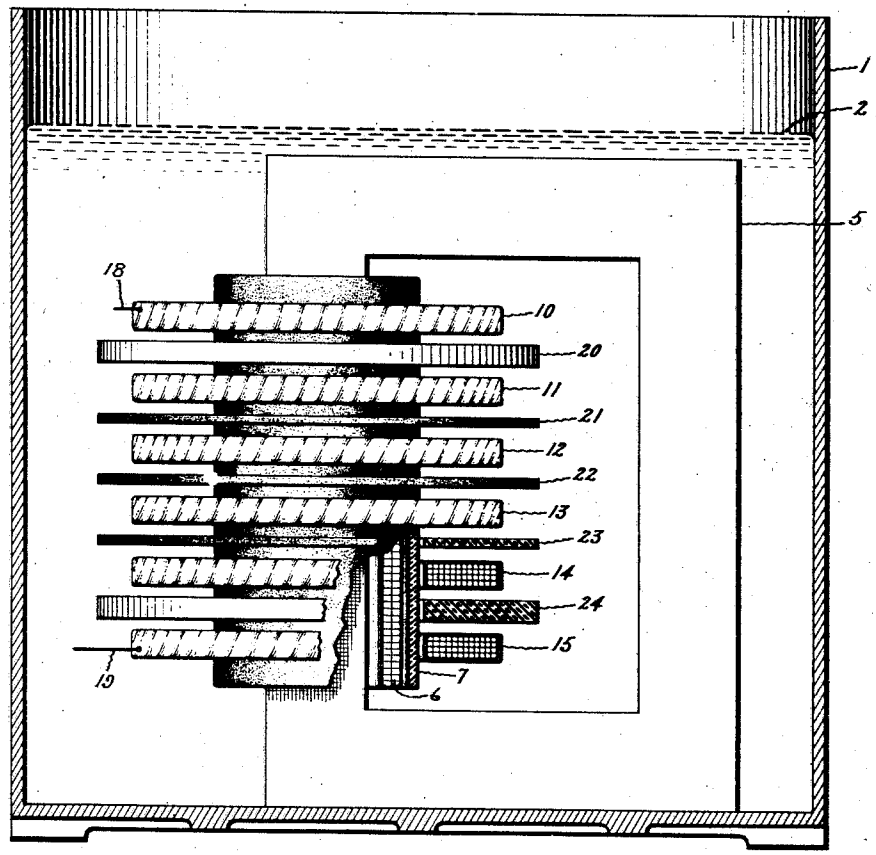
G. FACCIOLI.

ELECTRICAL APPARATUS.

APPLICATION FILED MAR. 11, 1919.

1,426,971. Patented Aug. 22, 1922.



Inventor:
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ELECTRICAL APPARATUS.

1,426,971. Specification of Letters Patent. Patented Aug. 22, 1922.

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To all whom it may concern:

Be it known that I, GIUSEPPE FACCIOLI, a citizen of the United States, residing at Pittsfield, county of Berkshire, State of Massachusetts, have invented certain new and useful Improvements in Electrical Apparatus, of which the following is a specification.

My invention relates both to electrical windings for various apparatus and to transformers. One object of my invention is to provide an electrical winding better adapted to withstand high frequency phenomena. Another object of my invention is to provide a transformer better adapted to withstand the high frequency phenomena to which some transformers, such as high voltage transformers connected to long and complex transmission systems, are likely to be subjected. Other objects of my invention will appear. The high frequency phenomena which I particularly contemplate guarding against is the steep traveling wave and its resulting phenomena.

Since I anticipate that my invention will find its greatest application in high voltage transformers, and since my invention in its broader aspect may be thoroughly understood from a consideration of its application to such a transformer, I shall for the sake of simplicity substantially limit the description of my invention to high voltage transformers.

One or both windings of transformers are commonly divided into coils which are commonly spaced apart for various purposes, such as insulation and ventilating or cooling. A fluid is commonly used between the coils for various reasons, such as assisting the cooling, for better insulation, etc. Considering only the high voltage or high tension winding of the transformer (although my invention may be applied to either or both of the windings), it is desirable to design the winding for a higher puncture voltage between the coils located adjacent the terminal or terminals of the winding than between coils located farther from the terminal or terminals of the winding. For this reason the distance between end or terminal coils is generally greater than the distance between other coils of the same winding and, therefore, if the prior common practice of transformer construction is followed, the electrostatic capacity between adjacent end or terminal coils is less than between the other coils of the winding. On the other hand, high frequency phenomena are better taken care of if the electrostatic capacity between coils is the same throughout the winding. I propose to reconcile these two apparently conflicting conditions by so using a plurality of insulating materials of different specific inductive capacities (preferably by using insulations of higher specific inductive capacities between the coils spaced farther apart), that no matter what the puncture voltage or the distance between any two adjacent coils may be, or how either or both these factors may vary through the winding, the capacitance or electrostatic capacity is substantially constant throughout. Where oil or air is used as the insulating fluid between all spaced coils of the same winding (following the present common practice), I use in addition to the oil or air between some or all of the spaced coils, solid insulating materials of such specific inductive capacities as to secure the desired equality of the electrostatic capacity between the coils of the winding.

While I contemplate that my invention will find its greatest usefulness in meeting these end coil conditions or some other non-uniformly spaced coil arrangement, the matter may be stated somewhat more broadly; thus my invention consists in substantially equalizing the capacitances between non-uniformly spaced major parts such as disc coils of a winding (irrespective of the reason of the spacing and the location of the wider spaces), or between major parts of a winding insulated from each other for different puncture voltages, by using therein between insulating materials of different specific inductive capacities.

The differentiation of my invention over the prior practice may be regarded to be this: Prior to my invention it was customary to insulate major parts as coils of a winding, in such a manner as to secure the desired ventilating space, the desired puncture voltage, etc. The capacitance between coils was allowed to assume whatever value might appear in meeting the other conditions. By my invention I include the capacitance as one of the conditions to be met in insulating the winding. That is, I so design and construct the winding that the

capacitance between its major parts is substantially the same throughout the winding, in addition to meeting the conditions of insulation strength, ventilation, etc.

In the accompanying drawing and the following description, I have illustrated and described in some detail the best embodiment of my invention of which I am now aware. The single figure of the drawing shows in elevation, partly in section, a transformer embodying my invention.

The transformer is submerged in insulating oil within a tank 1, the lever of the oil being indicated at 2. The transformer itself comprises a core 5, which in the instance illustrated, is of the two-legged rectangular type, the windings being placed about one leg as shown. The windings comprise a cylindrical low voltage winding 6 next to the core and concentric therewith a high voltage winding made up of a number of disc coils. Outside of the low voltage winding 6 is a cylinder 7 of insulating material for insulating the low voltage winding from the high voltage winding, and outside the cylinder 7 are the disc-coils 10, 11, 12, 13, 14 and 15 of the high voltage winding. For the purposes of this description the disc-coils 10 to 15 may be regarded as connected in series, the terminals of the high voltage winding being brought out at 18 and 19 as shown. Since the terminals 18 and 19 of the high voltage winding are brought out from the coils 10 and 15, these coils 10 and 15 are the end coils or terminal coils of the high voltage winding; to an extent, of course, the coils 11 and 14 are also end or terminal coils since they are located nearer the terminals 18 and 19 than the coils 12 and 13, although not directly connected to the terminals 18 and 19. Following the common practice, the coils 10 to 15 are spaced apart for the purpose of admitting between the coils, the oil in which the transformer is submerged; the layers of oil between the coils have two functions, namely, for ventilating or cooling the winding and for insulating the coils 10 to 15 from each other, or assisting in this insulation. Following the common practice farther, in addition to the insulating fluid, insulating collars 20 to 24 inclusive, of solid insulating material, are placed in the spaces between coils to secure additional insulation strength (higher puncture voltage), or for other purposes.

While the high voltage winding is connected to the line, the coils near each terminal, that is, the end or terminal coils, are at times subjected to greater differences of potential than the coils nearer the center of the winding. For this reason it is customary to space the end coils farther part than the center coils, or use thicker or a plurality of collars between end coils. This practice is illustrated in the drawing where it will be seen that the coils 10 and 15 are spaced farther from the coils 11 and 14 respectively than the coil 11 from the coil 12 or the coil 12 from the coil 13 or the coil 13 from the coil 14. For this and for other reasons it is desirable to space the coils non-uniformly throughout the winding, and by this non-uniform spacing or other arrangements resulting from the extra end coil insulator, there result different values of the capacitance between different coils. For example, the capacitance between coils 10 and 11 (supposing the transformer illustrated to follow the customary designs and constructions prior to my invention) is usually less than the capacitance between the coils 11 and 12 or between the coils 12 and 13. To what extent and in what order the capacitances are unequal between coils is dependent upon the design and construction of the particular transformer or winding.

In the transformer shown in the drawing, however, the capacitance between coils of the high voltage winding is made substantially uniform throughout the high voltage winding. I have accomplished this result by disposing insulation of higher specific inductive capacity between the more separated coils than between those coils which are closer together. The insulating materials between coils of the high voltage winding shown are the oil in which the transformer is submerged, and mica and pressboard for the collars. The specific inductive capacity of oil is about 2, the specific inductive capacity of pressboard about 4, and the specific inductive capacity of mica from 5 to 7 or (for the purposes of this description) say 6. The spaces between the coils 11 and 12, between coils 12 and 13, and between coils 13 and 14, are substantially equal in width. The spaces between the coils 10 and 11 and between coils 14 and 15 are also equal to each other, but each of these spaces is of somewhat greater width than that between any other two coils. To obtain equal capacitance between each two coils therefore, I use the same insulating materials (and thickness of insulating materials) between the coils 11 and 12, between 12 and 13, and between 13 and 14; but between the coils 10 and 11 and between the coils 14 and 15 I use insulating materials of a higher specific inductive capacity than between the other coils. Thus between coils 10 and 11 and between coils 14 and 15 I use two layers of oil (two oil ducts) separated by a collar 20 (or 24) of mica, and between each other two adjacent coils I use two layers of oil separated by a collar of pressboard. And by properly choosing the thicknesses or widths of the oil layers and the thicknesses or widths of the collars, I am able to secure

substantially the same capacitance between coils 10 and 11 as between coils 11 and 12 and likewise between every other two adjacent coils. The relative thicknesses or widths of the different layers of insulating materials to secure this result are readily determinable by anyone skilled in the art. The absolute thicknesses must, of course, be sufficient to secure at least the required insulation strength between every two adjacent coils; the absolute thicknesses are likewise readily determinable by those skilled in the art. For the purpose of illustration, I may point out that the following relative thicknesses of the different layers of insulating material indicated in the drawing give substantially, although not exactly, equal capacitance between the coils illustrated, assuming that the specific inductive capacities for these materials are those heretofore indicated and assuming also that the diameters of the disc coils are all alike as shown in the drawing. Assuming as a basis that the thickness or width of the mica collar 20 is 1, then the thickness or width of the mica collar 24 is likewise 1; the width of the oil space between the collar 20 and the coil 10 is $\frac{1}{2}$; the width of the oil space between the collar 20 and the coil 11 is also $\frac{1}{2}$; the width of the oil space between the coil 11 and the collar 21 is $\frac{9}{16}$; the width or thickness of the pressboard collar 21 is $\frac{3}{8}$; the width of the oil space between the collar 21 and the coil 12 is $\frac{9}{16}$; the widths or thicknesses of the oil spaces and pressboard collars between coils 12 and 13 and between coils 13 and 14 are respectively like those between coils 11 and 12; and the width or thickness of each of the two oil spaces between coils 14 and 15 is like that of each oil space between coils 10 and 11, namely $\frac{1}{2}$. It will be understood that these values are relative values only and not absolute values. In arriving at these relative widths or thicknesses, it will be observed that the solid insulation about each coil has been given no consideration. Whether in any case this material must be taken into consideration is dependent on whether it materially affects the distribution of capacitances.

The absolute thicknesses of the insulating layers may be anything so long as they bear the same relation to each other as these numbers, and the absolute thicknesses will be determined by the other considerations, such, for example, as the insulation strength (or puncture voltage) required between coils. That is, sufficient mica and oil must be placed between coils 10 and 11 to sustain their anticipated difference of potential, and likewise sufficient pressboard and oil must be placed between coils 11 and 12 to sustain their anticipated difference of potential; every other two coils of the winding illustrated being assumed to be related like 10 and 11 or 11 and 12, it is unnecessary to refer to them individually.

It will be seen that the high voltage winding of the transformer of the drawing has its capacitance between coils, in this instance the distinctive major parts of the winding, substantially uniformly distributed throughout the winding. How my invention may be applied to other forms of windings, and to other devices, will be understood by those skilled in the art from what has gone before. It will be understood, accordingly, that my invention is not limited to the transformer or high voltage winding illustrated in the drawing and described above, but that this embodiment of my invention is merely illustrative and that my invention is set forth in the following claims.

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

1. An electrical winding comprising a plurality of coils spaced different distances apart, and insulating means for insulating said coils from each other disposed in the spaces between the coils, said insulating means having specific inductive capacities and dimensions selected and proportioned to maintain equal capacitance effects between any pair of adjacent coils.

2. An electrical winding comprising a plurality of coils spaced different distances apart and adapted to be submerged in an oil insulating medium, and insulating collars disposed in the spaces between the coils; said collars being arranged and graded in specific inductive capacity and dimensions both with respect to the degree of space between coils and the resulting permittivities of their respective spaces when filled with oil whereby the capacitance of each pair of adjacent coils is made substantially equal.

3. An electrical winding comprising a plurality of coils spaced different distances apart, a cooling and insulating medium surrounding said coils, and insulating collars disposed in fixed space relation between the coils; said collars being arranged and graded in specific inductive capacity and dimensions both with respect to the distance between coils and the resulting permittivities of their respective spaces whereby the capacitance of each pair of adjacent coils is made substantially uniform throughout the winding.

4. An encased electrical apparatus comprising a magnetic core, a high voltage winding adapted to be submerged in a fluid insulating medium and composed of coils disposed in spaced relation on said core, the spaces between coils varying throughout the winding, and solid insulating material interposed in said spaces; said material being graded in specific inductive

capacity and dimensions both with respect to the resulting permittivity and the distance between coils of the respective spaces occupied by it whereby substantially to equalize the respective capacitances between coils throughout the winding.

5. An encased electrical apparatus comprising a magnetic core, high and low voltage windings respectively disposed on said core, said high voltage winding being composed of coils spaced different distances apart and adapted to be submerged in a cooling insulating fluid, and insulating collars of different thicknesses disposed in fixed space relation between the coils; the thickness of said collars and the nature of their material being proportioned and graded for their respective spaces with reference both to the distance between coils and their specific inductive capacities whereby the capacitances of each pair of adjacent coils is made substantially uniform throughout the high voltage winding.

In witness whereof, I have hereunto set my hand this seventh day of March, 1919.

GIUSEPPE FACCIOLI.