June 6, 1961 G. G. DOUCETTE, JR 2,987,684

ELECTRICAL APPARATUS

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Fig. 1.

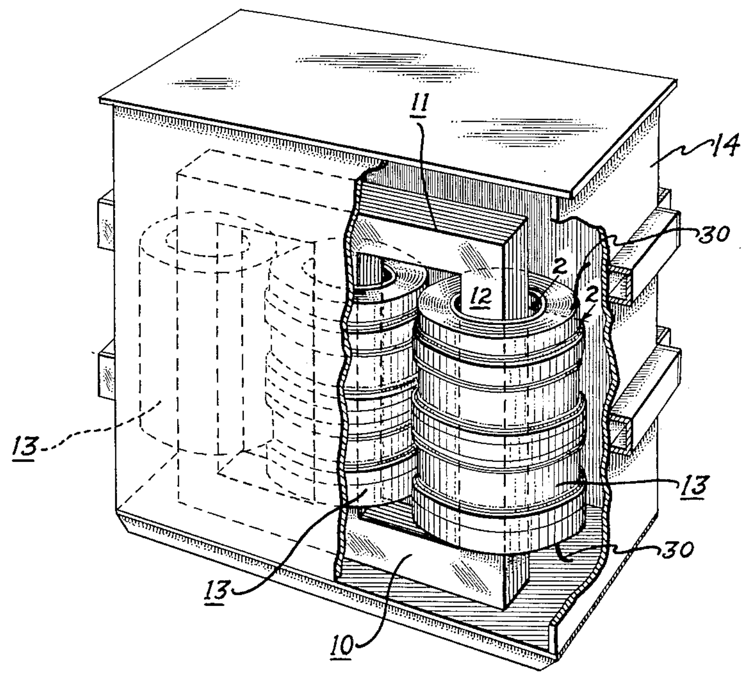

Fig. 3.

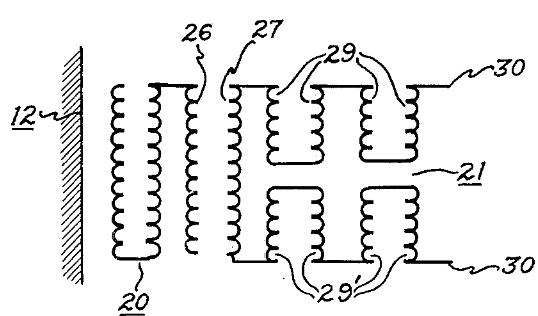

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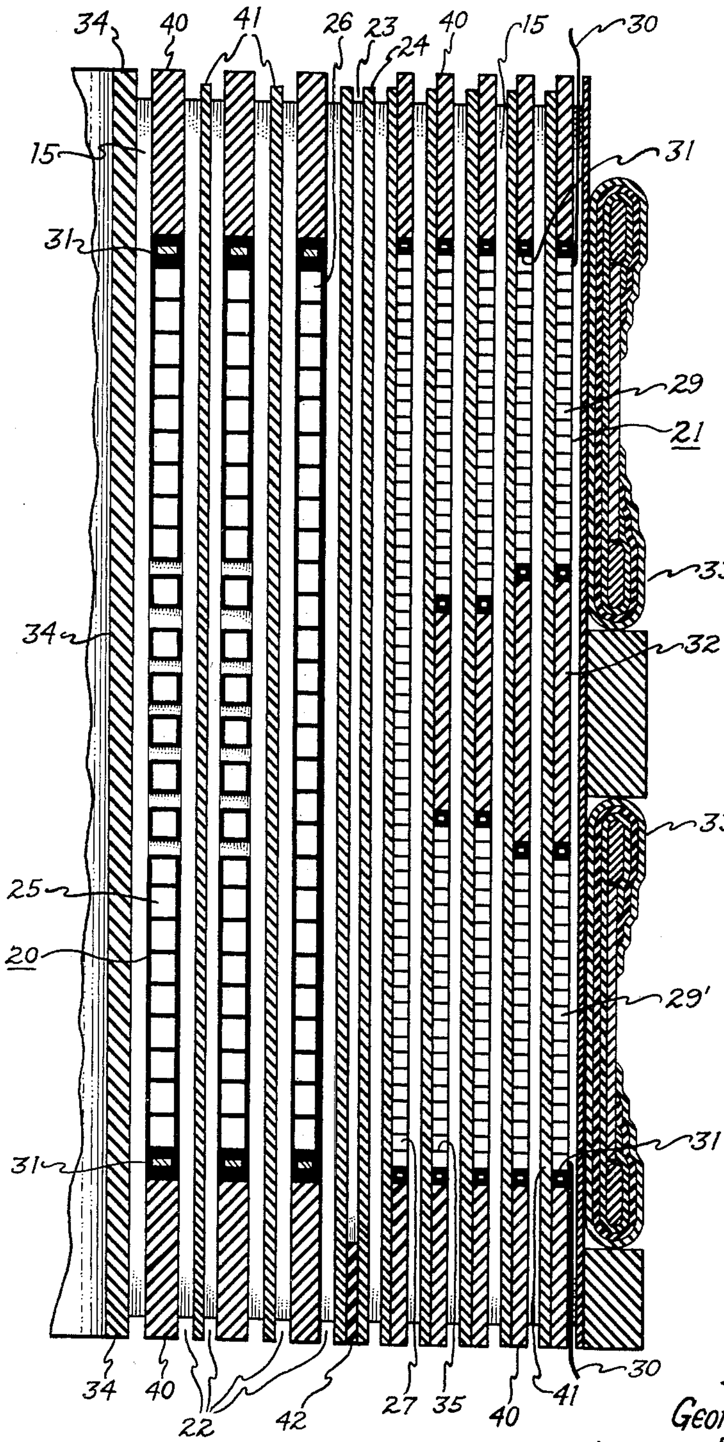
Fig. 2.



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ELECTRICAL APPARATUS

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3 Claims. (Cl. 336—12)

This invention relates to electrical apparatus and more in particular to an improved winding for such apparatus.

Electrical induction apparatus such as transformers and the like are conventionally made with a low voltage winding surrounding a magnetic core and a high voltage winding surrounding the low voltage winding. Because the high voltage winding and low voltage winding are at different potentials, they must be separated and insulated from each other. In order to reduce the size and weight of such apparatus, it is desirable that the gap separating the high voltage and low voltage windings be kept to a minimum. Since the amount of insulation and spacing between the high voltage winding and low voltage winding is a function of the potential difference between these two windings, one way of reducing the size of the gap is to arrange the windings in such a manner that the portions of the high and low voltage windings nearest to each other are at the closest electrical potentials practically obtainable in the apparatus. While winding arrangements constructed in accord with this principle have been proposed in the past, these arrangements have not been satisfactory because they do not lend themselves to mass production, assembly line techniques, and also they have required complicated channels for the flow of insulating and cooling fluid through the windings.

Accordingly, it is an object of my invention to provide an improved winding arrangement for electrical apparatus.

Another object of my invention is to provide an electrical transformer in which the spacing between high and low voltage windings is reduced to an acceptable minimum.

Other objects and advantages of my invention will become apparent from the following specification and the accompanying drawing.

Briefly stated, according to one aspect of my invention, the spacing between high voltage and low voltage layer windings is kept to an acceptable minimum by dividing some of the high voltage winding layers into axially spaced sections that are connected in series so that the layer closest to the low voltage winding is at the lowest practical potential. The turns of the closest layers of both high and low voltage windings are contiguous and the ends of these layers are shielded. This configuration also provides continuous axial fluid flow channels through the windings.

My invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing:

FIG. 1 is a perspective partially cross-sectional view of an embodiment of electrical apparatus in accordance with my invention.

FIG. 2 is a cross-sectional view taken along the line 2—2 in FIG. 1.

FIG. 3 is a schematic representation of the electrical winding of FIGS. 1 and 2.

Referring to FIG. 1, therein is illustrated an embodiment of the teachings of my invention. An electrical transformer **10** having a core **11** with a plurality of legs **12** and electrical windings **13** around each leg is disposed in a fluid-tight housing **14** in the well-known manner. The transformer may be provided with conventional accessories such as bushings, fluid expansion reservoirs, external heat exchangers, etc., but such equipment has not been illustrated because it forms no part of the present invention.

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In FIG. 2 the windings **13** are shown in greater detail. The windings **13** each comprise a layer wound low voltage winding **20** and a layer wound high voltage winding **21**. The windings are illustrated as being circular, but may assume other shapes without departing from the spirit of the invention. The individual layers of the high voltage and low voltage windings are spaced radially outwardly from each other in order to provide continuous axial channels **22** for the flow of a cooling and insulating fluid, such as transformer oil or a dielectric gas. Proper spacing between the components of the winding may be obtained by attaching vertically extending spacers **15** to the insulation between the layers. The low voltage winding **20** and high voltage winding **21** are separated by a gap or space **23**, the gap being provided with suitable insulating material, such as layers of paper **24**. The paper layers **24** may also be spaced radially from each other so as to provide axially extending fluid channels between the high and low voltage windings. Some of these channels may be blocked by barriers **42** to limit the flow of fluid to those channels adjacent the windings.

Each layer of the low voltage winding **20** comprises a plurality of axially wound turns of an insulated electrical conductor **25**. The individual layers may be insulated at the top and bottom by bands of insulating material **40**, and separated by cylinders of insulating material **41**. The turns of the radially outermost layer **26** of the low voltage winding are wound contiguous with each other in order to minimize stress concentrations that occur at the corners of each turn. Inner layers of the low voltage winding **20** may have the turns thereof spaced axially from each other at a central portion in order to axially balance the ampere-turns with those of spaced sections of the high voltage winding **21**.

In order to reduce the size of the gap **23** to an acceptable minimum and thus reduce the over-all size and weight of the transformer **10**, the high voltage winding **21** has been made in accordance with the teachings of my invention. By an acceptable minimum it is meant that the gap size is reduced to the smallest dimension at which the transformer **10** will pass the tests required by the trade to insure adequate safety factors against insulation breakdown. Since the size of the gap **23** is a function of the potential difference between the radially outermost layer **26** of the low voltage winding and the radially innermost layer **27** of the high voltage winding, the size of the gap **23** can be reduced to an acceptable minimum if these layers are arranged so as to be at the closest potentials practical. This can be accomplished by dividing some or all of the remaining high voltage winding layers into axially spaced winding sections **29** and **29'**. The sections **29** are connected in series, and the sections **29'** are also connected in series. The respective winding sections **29** and **29'** are also connected in series with the innermost layer **27** at opposite ends thereof. When employing this arrangement in delta connected apparatus, the leads **30** from the high voltage winding that are connected to the high voltage line are in the radially outermost winding layer and thus spaced the farthest distance from the low voltage winding. Consequently, the innermost high voltage winding layer **27** is at the lowest practical potential for a fully insulated layer winding arrangement. An examination of the schematic illustration of this winding arrangement in FIG. 5 will reveal that the innermost high voltage winding layer **27** is at roughly half the line potential. The turns of the innermost layer **27** are contiguous for the same reasons stated above with regard to the layer **26**.

The respective axially spaced high voltage winding sections 29 and 29' may be effectively insulated from each other by bands or rings of solid insulating material 32. The high voltage winding layers may be insulated at the top and bottom by bands of insulating material 40, and also separated by cylinders of insulating material 41 and spacers 15. The exterior of the winding 12 may be provided with conventional line shields 33. In order to eliminate stress concentrations at the ends of the high voltage and low voltage winding layers, each layer is provided with conventional shield means 31 at its outer ends.

It will be apparent from inspection of the drawing that a winding made in accordance with the teachings of my invention can be fabricated in the usual manner by winding the individual layers from separate lengths of insulated conductor material 35 and then connecting the ends of the individual conductors together by brazing. However, one of the advantages of a winding in accordance with my invention is that it is readily fabricated by mass production techniques. Once the fabrication of the winding 12 has been started by placing the insulating cylinder 34 on a mandrel (not illustrated), the winding 12 need never be taken from the mandrel until it is completed because the successive winding layers and insulation layers can easily be wound on top of each other. This eliminates the necessity of transporting partially fabricated windings from one place to another during the manufacturing operation. Thus, apparatus employing my improved electrical winding can be made by standardized assembly line methods of production.

Although the invention has been described with reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the scope of the invention. It is, therefore, intended that the appended claims cover all such equivalent variations as come within the true spirit and scope of the invention.

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

1. Electrical apparatus comprising a magnetic core extending in an axial direction, a low voltage winding comprising turns of an insulated conductor wound axially in concentric radially spaced layers so as to provide continuous axial fluid flow passages through the low voltage winding, the turns in the layer of said low voltage winding spaced radially farthest from said core being contiguous, a high voltage winding comprising turns of an insulated conductor wound axially in concentric radially spaced layers so as to provide continuous axial fluid flow passages through the high voltage winding, there being a radial gap separating said high and low voltage windings, the turns in the layer of said high voltage winding closest to said low voltage winding being contiguous, other layers of said high voltage winding comprising two winding sections separated axially from each other by insulating means, radially adjacent layers in the respective high voltage winding sections being serially connected so that the terminal ends of the high voltage winding occur in the layer spaced radially farthest from said low voltage winding, and means shielding the end turns of said closest high voltage winding layer and said farthest low voltage winding layer, whereby the electrical stress across, and also the size of, the gap between said high and low voltage windings is reduced to an acceptable minimum.

2. Electrical apparatus comprising a magnetic core extending in an axial direction, a low voltage winding comprising turns of an insulated conductor wound axially in concentric radially spaced layers so as to provide continuous axial fluid flow passages through the low voltage winding, the turns in the layer of said low voltage winding spaced radially farthest from said core being contiguous, a high voltage winding comprising turns of an insulated conductor wound axially in concentric radially spaced layers so as to provide continuous axial fluid flow passages through the high voltage winding, there being a radial gap separating said high and low voltage windings, the turns in the layer of said high voltage winding closest to said low voltage winding being contiguous, the remaining layers of said high voltage winding comprising two winding sections separated from each other in said axial direction by solid rings of insulating material, radially adjacent layers in the respective high voltage winding sections being serially connected so that the terminal ends of the high voltage winding occur in the layer spaced radially farthest from said low voltage winding, the turns in some of the low voltage winding layers being axially spaced to balance ampere-turns, and means shielding the turns at opposite ends of the high voltage and low voltage windings, whereby the electrical stress across, and also the size of, the gap between said high and low voltage windings is reduced to an acceptable minimum.

3. A fluid-cooled polyphase electrical transformer comprising an enclosure, a dielectric fluid in said enclosure, a magnetic core in said enclosure, said core having a plurality of legs extending in an axial direction, a low voltage winding around each core leg, each low voltage winding comprising turns of an insulated conductor wound axially in concentric radially spaced layers so as to provide continuous axial fluid flow passages through the low voltage winding, the turns in the layer of each low voltage winding spaced radially farthest from said core being contiguous, a high voltage winding around each low voltage winding comprising turns of an insulated conductor wound axially in concentric radially spaced layers so as to provide continuous axial fluid flow passages through the high voltage windings, there being a radial gap separating each pair of high and low voltage windings, the turns in the layers of the high voltage windings closest to the low voltage windings being contiguous, the remaining layers of said high voltage windings comprising two winding sections separated axially from each other by solid rings of insulating material, radially adjacent layers in the respective high voltage winding sections being serially connected so that the terminal ends of the high voltage windings occur in the layers spaced radially farthest from said low voltage windings, the terminal ends of the respective high voltage windings being delta connected so that said closest layers are at approximately one-half of line potential, the turns in some of the low voltage winding layers being axially spaced to balance ampere-turns, and means shielding the turns at opposite ends of each high voltage winding layer and each low voltage winding layer, whereby the electrical stress across, and also the size of, the gaps between said high and low voltage windings is reduced to an acceptable minimum.

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