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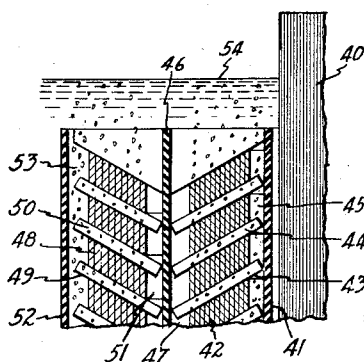
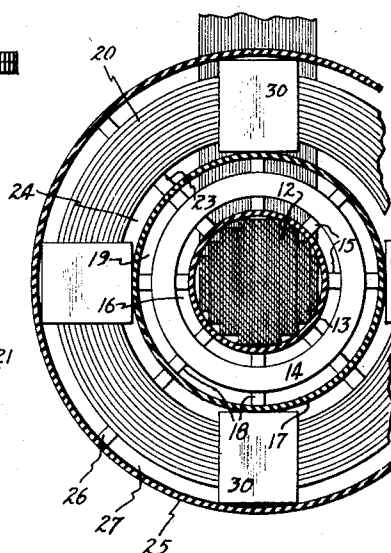
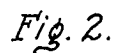
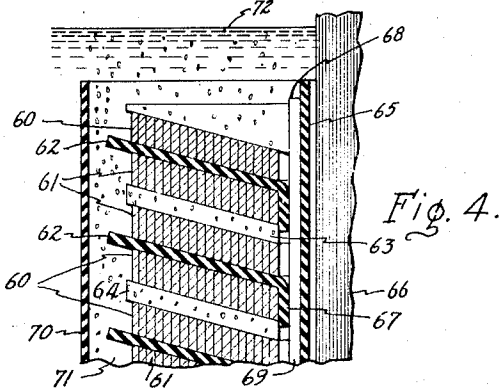


Fig. 3.

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VAPORIZATION COOLED STATIONARY ELECTRICAL INDUCTION APPARATUS

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This invention relates to a vaporization cooled stationary electrical induction apparatus, and more particularly, to a vaporization cooled stationary electrical induction apparatus having cone or dish-shaped electrical windings.

A natural convection cooled stationary electrical induction apparatus having cone or dish-shaped electrical windings is well known in the prior art. Such an apparatus was an improvement over the natural convection cooled stationary electrical induction apparatus having flat disk-shaped electrical windings. By substituting cone or dish-shaped electrical windings for the flat disk-shaped windings it was discovered that the natural convection of the cooling fluid could be increased. However, such a change does not appear to be justifiable with all types of cooling fluids. Where the cooling fluid used is a gas, a considerable gain is made by using cone or dish-shaped windings as versus flat disk-shaped windings. When a liquid is used as the cooling fluid though, the gain made by using cone or dish-shaped windings is comparatively inconsequential.

Accordingly, it is an object of this invention to provide in a stationary electrical induction apparatus having cone or dish-shaped electrical windings an effective cooling system utilizing a liquid as the cooling fluid.

My invention comprises a vaporization cooled stationary electrical induction apparatus having hollow truncated cone-shaped superposed electrical winding layers which are spaced axially from each other to define cooling ducts therebetween, the cooling fluid for said apparatus comprising a liquid whose boiling point temperature is within the normal operating temperature range of said apparatus whereby the vapor bubbles formed in said liquid during operation of said apparatus will be accelerated rapidly by their natural buoyancy through said cooling ducts.

The invention will be better understood by considering 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 an end elevation view, partly in section, and partly broken away, of one form of my invention. Fig. 2 is a sectional view of the apparatus shown in Fig. 1, the section being taken along the line 2—2 of Fig. 1. Fig. 3 is a detail view similar to Fig. 1 of another form of my invention. Fig. 4 is a detail view like Fig. 3 of still another form of my invention.

Referring now to the drawing, and more particularly to Fig. 1, shown therein is a stationary electrical induction apparatus or transformer comprising a tank or casing 10 having a dielectric cooling liquid 11 therein. Immersed within liquid 11 is a magnetic core, only one vertical end leg portion 12 of which is shown. Surrounding vertical leg 12 is an insulating material cylinder 13. Tele-

scopedically surrounding insulating cylinder 13 and radially spaced therefrom are barrel-type low voltage electrical windings 14. Windings 14 are radially spaced from insulating cylinder 13 by vertical spacer members 15 where-

by a vertical cooling duct 16 is defined between windings 14 and insulating cylinder 13. Concentric with barrel-type windings 14 is an insulating cylinder 17 radially spaced therefrom. Insulating cylinder 17 is radially spaced from barrel-type windings 14 by vertical spacer members 18 whereby an annular vertical cooling duct 19 is defined therebetween. Surrounding insulating cylinder 17 are a plurality of vertically superposed vertically spaced hollow inverted frustum or truncated cone-like layers 20 of high voltage electrical windings. Layers 20 are vertically or axially spaced from each other by narrow radially extending spacer members 21 whereby radially outward and upwardly extending annular cooling ducts 22 are defined between the layers 20. The layers 20 are radially spaced from insulating cylinder 17 by vertical spacer members 23 whereby a vertical cooling duct 24 in communication with ducts 22 is defined between the superposed layers 20 and insulating cylinder 17. Concentric with the axially aligned layers 20 is an insulating cylinder 25. Insulating cylinder 25 is radially spaced from the superposed layers 20 by vertical spacer members 26 whereby an annular vertically extending cooling duct 27 is defined between the superposed layers 20 and insulating cylinder 25. Insulating cylinder 25 is spaced from the side walls of tank 10 by an annular vertical cooling duct 28. The vertically spaced and superposed layers 20 are supported on radially extending wedged-shaped blocks 29. Similar but reversed radially extending wedge-shaped blocks 30 are positioned upon the uppermost of the layers 20. As is well known in the art, the superposed and axially spaced layers 20 can be rigidly clamped between the wedge-shaped block 29 and 30. Tank or casing 10 is hermetically sealed by a cover 31. Positioned on the cover 31 and in communication with the interior of tank 10 are condensing tubes 32.

In my invention the dielectric cooling liquid 11 is a liquid which will form vapors while the electrical windings are at normal operating temperature so that a large quantity of heat is always being removed by vaporization and condensation cooling. That is, the dielectric cooling liquid 11 should have a boiling point temperature within the desired operating temperature range of the electrical windings. A variety of liquids can be used amongst which are the freons and fluorocarbons which are characterized by boiling point temperatures within the normal operating temperature range of most electrical windings for stationary electrical induction apparatus.

During the operation of the stationary electrical induction apparatus disclosed in Figs. 1 and 2 the electrical windings become heated. This heat is transferred to the dielectric cooling liquid 11. Inasmuch as liquid 11 has a boiling point temperature within the normal operating temperature range of the stationary electrical induction apparatus vapor bubbles will be formed in liquid 11. As seen in Fig. 1, the vapor bubbles formed in ducts 16 and 19 will rise vertically therein towards the surface of liquid 11. The vapor bubbles formed in the radial and upward or inclined cooling ducts 22 will rapidly rise in said ducts 22 due to their natural buoyancy towards the vertical cooling duct 27. Accordingly, the natural convection circulation of the cooling liquid 11 will be increased. There will be a high concentration of vapor bubbles in the vertical cooling duct 27 and practically no vapor bubbles in vertical duct 24. This is due to the fact that the frustum or truncated cone-shaped layers 20 slope from their inner circumference upwardly towards their outer circumference wherein the radial cooling ducts 22 have a similar slope whereby the vapor bubbles formed always tend to move up ducts 22 into duct 27 which is in communication with ducts 22.

The wisdom of having a minimum concentration of vapor bubbles in vertical cooling duct 24 is that the vertical cooling duct 24 positioned between the high voltage windings 20 and the low voltage windings 14 is a high electrical stress region. A liquid is generally a better electrical insulating medium than a gas. Accordingly, if only liquid is present within cooling duct 24 the degree of insulation between high voltage windings 20 and low voltage windings 14 is increased. Similarly, the conical shape of windings 20 and the inclined slope of ducts 22 prevents excessive bubble accumulation underneath windings 20 as would be the situation with flat disk-type windings. Excessive bubble concentration between windings 20 would markedly decrease the dielectric strength between the windings 20.

The high concentration of vapor bubbles in vertical cooling duct 27 performs a very useful function. The vapor bubbles in duct 27 constitute a sound insulating barrier to decrease the noise produced by the stationary electrical induction apparatus. Likewise the vapor bubbles in ducts 16 and 19 perform a similar function. Also, rapid acceleration of the cooling liquid and vapor bubbles, by virtue of the well defined ducts 16, 19, 24, 22 and 27 aids in the removal of otherwise stagnant films from the electrical winding surfaces.

After the vapor bubbles have risen in ducts 16, 19 and 27 they will rise to the surface of liquid 11 and thence upward towards the condensing tubes 32. After the vapor bubbles have entered condensing tubes 32 they will be condensed therein. The liquid resulting from the condensed vapor bubbles will flow from the condensing tubes 32 back into the insulating liquid 11. The ends of the condensing tubes 32 are preferably positioned immediately above the annular vertical cooling duct 28 whereby the condensed liquid from cooling tubes 32 will tend to travel down vertical cooling duct 28 towards the bottom of the tank. During this travel of the condensed liquid down duct 28 said liquid will be additionally cooled by coming into contact with the side wall of tank 10. Ultimately said condensed and cooled liquid will reach the bottom of the tank where it can re-enter the cooling ducts 16, 19 and 24 to repeat its cooling cycle. The liquid which enters duct 24 will again be vaporized whereby the vapor bubbles will rise in radial ducts 22 towards the vertical duct 27 and then on to the condensing tubes 32.

Referring now to Fig. 3, shown therein is another embodiment of my invention. In Fig. 3 a vertical magnetic core leg 40 is surrounded by an insulating material cylinder 41. Concentric with insulating cylinder 41 are a plurality of vertically superposed vertically spaced low voltage layers 42. Layers 42 are wound in a hollow frustum or truncated cone-shaped manner with the layers sloping upwardly from their outer circumference towards their inner circumference. Layers 42 are axially or vertically spaced from each other by radial spacers 43 whereby radial cooling ducts 44 are defined between the low voltage layers 42. The superposed low voltage layers 42 are radially spaced from insulating cylinder 41 by a vertically extending annular cooling duct 45. Radially spaced from and surrounding layers 42 is an insulating cylinder 46. Defined by insulating cylinder 46 and the outer circumference of the layers 42 is a vertical annular cooling duct 47. Telescopic with the insulating cylinder 46 are radially spaced therefrom are a plurality of axially aligned axially spaced hollow frustum or dish-like high voltage layers 48. High voltage layers 48 slope upwardly from their inner circumference towards their outer circumference. Layers 48 are axially spaced from each other by radial spacers 49 whereby radial ducts 50 are defined between the high voltage layers 48. Between the inner edges of the high voltage layers 48 and insulating cylinder 46 is defined an annular vertically extending cooling duct 51. Surrounding the high voltage layers 48 is an insulat-

ing cylinder 52 which is spaced from layers 48 by a vertical cooling duct 53.

As in the embodiment of my invention shown in Figs. 1 and 2, the Fig. 3 embodiment of my invention is submerged within a dielectric cooling liquid 54 whose boiling point temperature is within the operating temperature range of the electrical windings. In the form of my invention shown in Fig. 3 inasmuch as the radial and upward cooling ducts 50 and 44 slope away and upwardly from the insulating cylinder 46 there will be a high concentration of vapor bubbles in the vertical cooling ducts 45 and 53. There will be a minimum concentration of vapor bubbles in the vertical cooling ducts 47 and 51. Accordingly, the degree of insulation between the high voltage windings 48 and the low voltage windings 42 is substantially increased in this form of my invention. As in the prior form of my invention the concentration of vapor bubbles in vertical ducts 45 and 53 will serve as a sound insulating barrier. After the vapor bubbles have risen in vertical ducts 45 and 53 to the condensing tubes, not shown, the condensed vapor bubbles will thereafter return to the body of liquid 54 and traverse down towards the bottom of the tank whereupon the cooled liquid can again enter vertical cooling ducts 51 and 47 to be vaporized in radial ducts 50 and 44.

Referring now to Fig. 4, shown therein is still another embodiment of my invention wherein the low voltage winding layers 60 and the high voltage winding layers 61 have a hollow inverted truncated cone shape. The layers are interleaved with each other so that a pair of high voltage layers 61 is alternated with a pair of low voltage layers 60, and vice versa. Any immediately adjacent low voltage layer 60 and high voltage layer 61 are spaced from each other by an inverted hollow truncate cone-shaped insulating material barrier 62 inasmuch as the space therebetween is a high voltage stress region. The radially outermost portions of barriers 62 extend radially beyond immediately adjacent layers 60 and 61 to increase the electrical creep distance therebetween. For a similar reason the radially innermost portions of the barriers 62 are flanged over.

Each layer of the alternated pair of layers 60 and 61 are spaced from each other so that radial cooling ducts 63 are defined therebetween with no insulating material barriers therebetween inasmuch as the space therebetween is not as high an electrical stress region as between an adjacent low voltage layer 60 and high voltage layer 61. Radial spacers 64 space the layers of the alternated pairs of low or high voltage layers 60 and 61 from each other to define the upwardly and radially outwardly inclined annular ducts 63.

Layers 60 and 61 concentrically surround an insulating material cylinder 65 concentrically disposed about a leg portion 66 of a transformer core. Between the vertically extending flanges 67 of barriers 62 and cylinder 65 are vertically extending spacer members 68 defining an annular vertically extending cooling duct 69 in communication with annular ducts 63. Disposed about the vertically stacked layers 60 and 61 and spaced therefrom is an insulating material cylinder 70 defining an annular vertically extending cooling duct 71 in communication with ducts 63.

As in the prior forms of my invention, the electrical apparatus is submerged in a dielectric insulating liquid 72 which has a boiling point temperature within the normal operating temperature range of the electrical apparatus. The vapor bubbles formed in the ducts 63 will rise rapidly therein into the duct 71 and thence on to the not shown condensing tubes. A high concentration of bubbles will be present in duct 71 to form a sound insulating barrier, and the rapidly rising bubbles and liquid in ducts 63, 69, and 71 will remove any stagnant films from the exterior surfaces of layers 60 and 61.

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While there have been shown and described particular embodiments of the invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention, and that it is intended by the appended claims to cover all such changes and modifications as fall 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. A vaporization cooled stationary electrical induction apparatus comprising a plurality of vertically superposed and vertically spaced layers of hollow inverted frustum-like electrical windings defining a plurality of annular cooling ducts therebetween parallel therewith, said layers surrounding an electrical insulating material cylinder and radially spaced therefrom to define a vertically extending cooling duct therebetween, another electrical insulating material cylinder surrounding said layers and radially spaced therefrom to define another vertically extending cooling duct therebetween, both of said vertically extending cooling ducts in communication with said annular cooling ducts, said apparatus submerged within and wetted by a dielectric cooling liquid having a boiling point temperature within the normal operating temperature range of said apparatus whereby vapor bubbles are formed in said liquid during operation of said apparatus, said vapor bubbles rapidly accelerated by their natural buoyancy through said annular cooling ducts into said another vertically extending cooling duct and upwardly of said another vertically extending cooling duct, said vapor bubbles concentrated in said another vertically extending cooling duct, said concentrated vapor bubbles comprising a sound insulating barrier surrounding said apparatus, said rapidly accelerated vapor bubbles causing rapid acceleration of said liquid through all of said cooling ducts, said rapidly accelerated vapor bubbles and liquid prohibiting the formation of stagnant liquid films on said windings.

2. A stationary electrical induction apparatus comprising high and low voltage electrical windings separated by an electrical insulating material cylinder, said low voltage windings positioned within said cylinder and said high voltage windings exteriorly surrounding said cylinder, said high voltage windings radially spaced from said cylinder and defining a vertical cooling duct therebetween, said high voltage windings comprising a plurality of vertically superposed and vertically spaced hollow frustum-shaped layers of electrical windings defining cooling ducts therebetween, said last-mentioned cooling ducts in communication with said vertical cooling duct and extending upward and radially outward from said vertical cooling duct, said apparatus submerged in and wetted by a dielectric cooling liquid having a boiling point temperature within the normal operating temperature range of said high and low voltage electrical windings whereby vapor bubbles are formed in said liquid during operation of said apparatus, said vapor bubbles rapidly rising in said upward and radially outward cooling ducts whereby there are substantially no vapor bubbles concentrated in said vertical cooling duct.

3. In a stationary electrical induction apparatus as in claim 2, wherein another vertical cooling duct positioned radially outward of said high voltage electrical windings is in communication with said upward and radially outward cooling ducts, said vapor bubbles substantially concentrating in said another vertical cooling duct.

4. A stationary electrical induction apparatus comprising a vertical magnetic core leg surrounded by electrical windings, said windings comprising low voltage and high voltage windings, said low voltage windings positioned radially inward of said high voltage windings, said high voltage windings comprising a plurality of vertically superposed, vertically spaced, hollow in-

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verted frustum-like winding layers, an electrical insulating material cylinder positioned between said low voltage windings and said high voltage windings, said apparatus immersed in and wetted by a dielectric cooling fluid comprising a liquid whose boiling point temperature is within the normal operating temperature range of said apparatus whereby vapor bubbles are formed in said liquid during operation of said apparatus, said plurality of high voltage winding layers radially spaced from said insulating cylinder and defining a vertically extending cooling duct therebetween, said vapor bubbles rising between said vertically spaced layers and accelerated by their natural buoyancy radially outward from between said vertically spaced layers, said vapor bubbles concentrated between said layers and the interior side walls of a tank enclosing said apparatus whereby a sound insulating barrier is formed by said concentrated vapor bubbles, said vertical cooling duct having a minimum of vapor bubbles concentrated therein.

5. A stationary electrical induction apparatus comprising high and low voltage electrical windings separated from each other by an electrical insulating material cylinder, said low voltage electrical windings comprising barrel-type electrical windings positioned interiorly of said cylinder and radially spaced therefrom to define a first vertically extending cooling duct therebetween, said high voltage electrical windings comprising a plurality of axially aligned and axially spaced hollow inverted truncated cone-like layers of electrical windings defining a plurality of annular cooling ducts therebetween and parallel therewith, said layers concentrically disposed about said cylinder and radially spaced therefrom to define a second vertically extending cooling duct therebetween, another electrical insulating material cylinder concentrically disposed about said layers and radially spaced therefrom to define a third vertically extending cooling duct therebetween, said second and third vertically extending cooling ducts in communication with said annular cooling ducts, said annular cooling ducts sloping upwardly from said second vertically extending cooling duct to said third vertically extending cooling duct, said apparatus submerged within and wetted by a dielectric cooling liquid having a boiling point temperature within the normal operating temperature range of said apparatus whereby vapor bubbles are formed in said liquid during operation of said apparatus, said vapor bubbles rapidly accelerated by their natural buoyancy upwardly through all of said cooling ducts, said rapidly accelerated bubbles causing acceleration of said liquid through all of said cooling ducts whereby the formation of stagnant liquid films on said high and low voltage electrical windings is substantially impeded, the vapor bubbles accelerated upwardly of said annular cooling ducts entering said third vertically extending cooling duct and concentrating therein to form a sound insulating barrier surrounding said apparatus.

6. A stationary electrical induction apparatus comprising high and low voltage electrical windings separated from each other by an electrical insulating material cylinder, said low voltage windings comprising a plurality of vertically superposed, vertically spaced, hollow frustum-shaped winding layers, said layers sloping upwardly from their radially outer edges towards their radially inner edges and said spaced layers defining a plurality of annular cooling ducts therebetween parallel therewith, said layers positioned within said cylinder and spaced therefrom to define a vertical cooling duct therebetween, said vertical cooling duct in communication with said annular cooling ducts, said high voltage windings comprising a plurality of vertically superposed, vertically spaced, hollow frustum-shaped winding layers, said high voltage layers inverted with respect to said low voltage layers, a plurality of annular cooling ducts

defined between said spaced high voltage winding layers and parallel therewith, said high voltage layers surrounding said insulating cylinder and spaced therefrom to define a vertical cooling duct therebetween in communication with said high voltage layer defined annular cooling ducts, said apparatus submerged within and wetted by a dielectric cooling liquid having a boiling point temperature within the normal operating temperature range of said high and low voltage electrical windings whereby vapor bubbles are formed in said liquid during operation of said apparatus, said vapor bubbles rising rapidly in said annular cooling ducts away from said vertical cooling ducts whereby substantially no vapor bubbles are concentrated in said vertical cooling ducts.

7. In an apparatus as in claim 6, wherein another vertical cooling duct is positioned radially inward of said low voltage layers, said another vertical cooling duct being in communication with the annular cooling ducts defined by said low voltage layers, and another vertical cooling duct is positioned radially outward of said high voltage layers and is in communication with the annular cooling ducts defined by said high voltage layers, said vapor bubbles being concentrated in said another vertical cooling ducts, said another vertical cooling ducts concentrated vapor bubbles comprising sound insulating barriers for said apparatus.

8. A stationary electrical induction apparatus comprising a vertically disposed magnetic core leg portion surrounded by an electrical insulating material cylinder, said insulating material cylinder surrounded by high and low voltage electrical windings radially spaced therefrom and defining a vertically extending cooling duct therebetween, said windings comprising a plurality of vertically superposed and axially aligned hollow inverted truncated cone-like high and low voltage electrical winding layers interleaved with each other, said layers interleaved with each other whereby pairs of high voltage layers are alternated with pairs of low voltage layers and vice versa, immediately adjacent high and

low voltage layers having a hollow inverted truncated cone-like electrical insulating material barrier therebetween, each of the layers of said alternated pairs of high and low voltage layers vertically spaced from each other and defining annular cooling ducts therebetween parallel therewith, another electrical insulating material cylinder concentrically disposed about said high and low voltage electrical windings and radially spaced therefrom to define another vertically extending cooling duct therebetween, both of said vertically extending cooling ducts in communication with said annular ducts, said apparatus submerged in and wetted by a dielectric cooling liquid having a boiling point temperature within the normal operating temperature range of said apparatus whereby vapor bubbles are formed in said liquid during operation of said apparatus, said vapor bubbles rapidly accelerated by their natural buoyance upwardly through all of said cooling ducts whereby circulation of said liquid through all of said cooling ducts is accelerated thereby impeding the formation of stagnant liquid films on said high and low voltage electrical windings, the vapor bubbles accelerated upwardly of said annular cooling ducts entering said another vertically extending cooling duct and concentrated therein, said concentrated vapor bubbles comprising a sound insulating barrier surrounding said apparatus.

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