

March 17, 1953

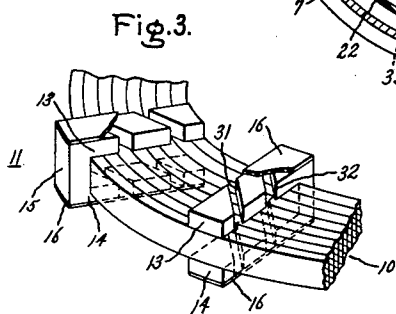
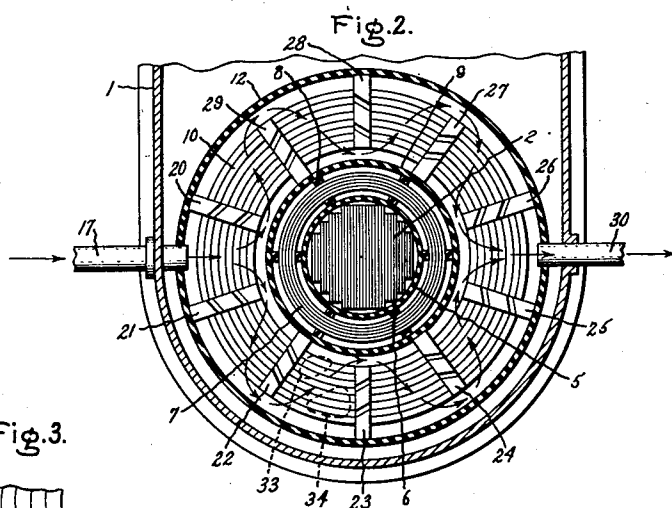
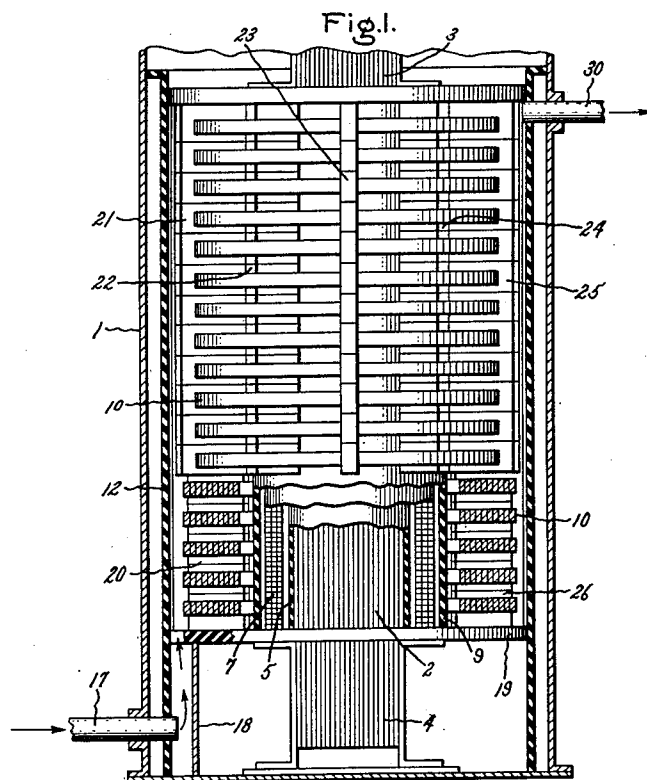
W. J. BILODEAU

2,632,041

TRANSFORMER COOLING DUCT CONSTRUCTION

Filed Feb. 11, 1950

2 SHEETS—SHEET 1



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2 SHEETS—SHEET 2

Fig. 5.

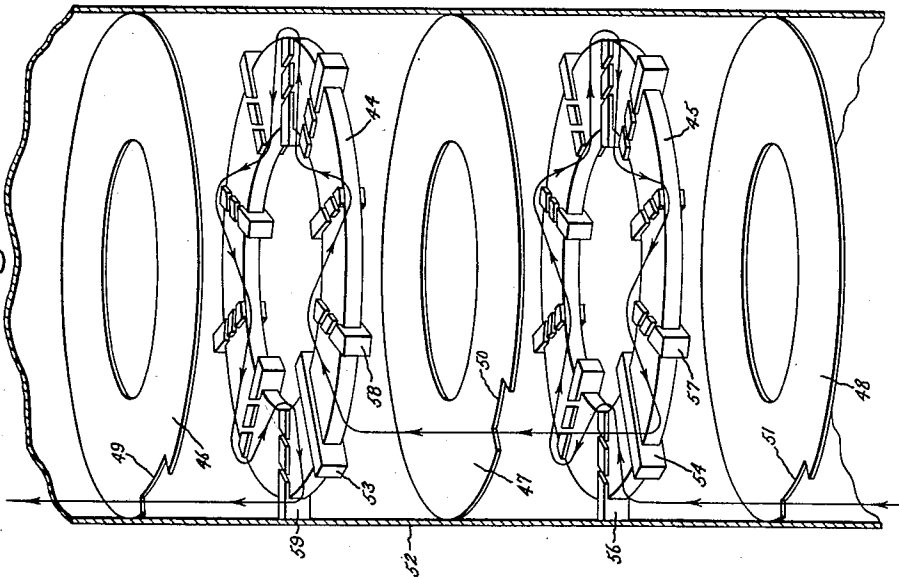
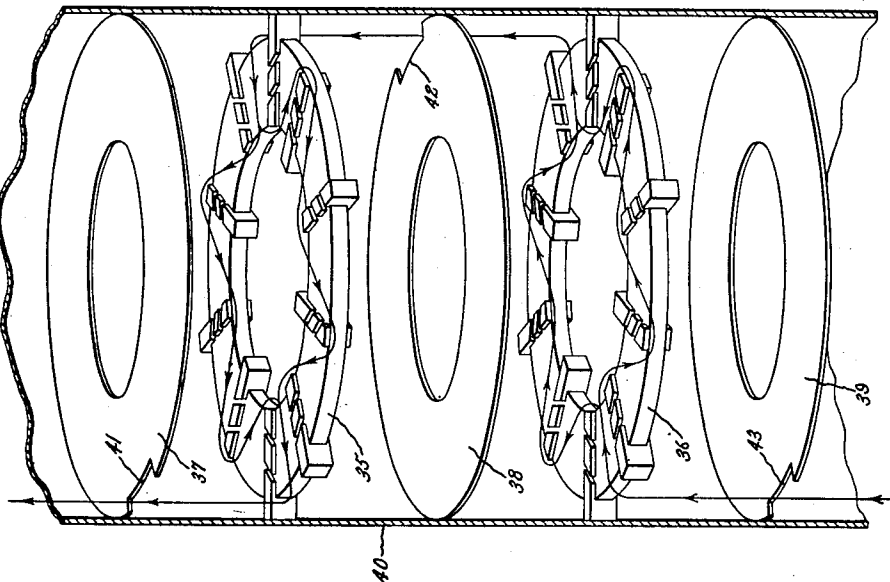


Fig. 4.



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UNITED STATES PATENT OFFICE

2,632,041

TRANSFORMER COOLING DUCT
CONSTRUCTIONWilfred J. Bilodeau, Windsor, Mass., assignor to
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7 Claims. (Cl. 175-356)

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This invention relates to stationary electrical induction apparatus, and more particularly to cooling means for such apparatus.

In the construction of large size stationary electrical induction apparatus, such as large transformers, it is practically universal practice to provide some type of cooling system for such apparatus. This invention relates to an improved cooling arrangement using forced oil flow for stationary electrical induction apparatus having disk-type coil windings.

It is an object of this invention to provide a construction which will result in an improved flow of cooling fluid through the windings of a stationary electrical induction apparatus so as to provide a more efficient heat removal from the electrical windings.

It is a further object of this invention to provide a construction which, by using standard design parts for directing cooling fluid flow through the windings of a stationary electrical induction apparatus, will be easy to fabricate and assemble, and, therefore, more economical to manufacture than constructions presently in use.

In accomplishment of these objectives, this invention provides a cooling arrangement for stationary electrical induction apparatus having disk-type coil windings in which conventional radial spacer members between the disk coil windings are so arranged as to provide a serpentine fluid flow circumferentially of the coil windings.

Hereinafter in this specification, I shall use an electrical transformer having disk-type coil windings by way of example as the stationary electrical induction apparatus to which my invention is applied. However, it will be understood that my invention may be equally well applied to any other type of stationary electrical induction apparatus having disk-type coil windings.

The features of this invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and use, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 represents a front elevation, partially cut away, of a transformer having cooling ducts constructed in accordance with my invention, and and in which the disk coils are in parallel with one another with respect to the flow of cooling

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liquids; Fig. 2 represents a plan view in cross-section of the transformer structure shown in Fig. 1; Fig. 3 shows an enlarged detail view of one of the cooling ducts constructed in accordance with my invention; while Figs. 4 and 5 represent modifications of my invention in which the elements are so arranged as to provide a series flow of cooling liquid, rather than a parallel flow as in the arrangement of Fig. 1.

In the construction of Figs. 1 and 2, I provide for simultaneous axial entry of cooling fluid to all of the windings, a dual circumferential flow through the windings with alternate in and out radial passes, with a final exit of the oil flow on the side of the coil stack opposite to the side of entry.

Referring now to the drawing, there is shown in Figs. 1 and 2 a transformer with an outer tank or casing 1 in which there is contained a magnetic core having two winding legs 2 (only one of which is shown) connected by yoke members 3 and 4. Concentrically arranged about each of the leg members 2 are high and low voltage windings, which will be described hereinafter in more detail. Since the windings about each of the respective leg members 2 are the same, only one leg member with its associated windings is shown. However, it will be understood that the transformer is comprised of at least two such legs 2, each having an identical winding arrangement.

Concentrically mounted about winding leg 2 is an axial insulating cylinder 5 which is separated by axial spacer members 6 from a low voltage winding 7. Low voltage winding 7 is wound in the form of a cylinder, and is separated by axial spacers 8 from concentric insulating cylinder 9. Spaced radially outwardly from insulating cylinder 9 are disk coils 10, which are stacked axially in superposed relation, and constitute the high voltage winding of the transformer. An insulating cylinder 12 is spaced radially outwardly of the disk coils 10.

In order to provide suitable cooling ducts between the stacked disk coils 10, the individual disk coils are separated from one another in the vertical or axial plane by means of radial spacer members 11, which are symmetrically arranged about the circumference of the interspace between the coils. Several of the radial spacer members 11 are shown in detail in Fig. 3.

The radial spacer members 11 serve the dual function of spacing the disk coils 10 axially from one another and also of spacing the disk coils radially from insulating cylinders 9 and 12. As

will be explained hereinafter, the arrangement and construction of the radial spacer members 11 also provide a predetermined oil flow pattern. Cylinders 9 and 12 are concentric with disk coils 10, with cylinder 9 being positioned radially inwardly of the disk coils, and cylinder 12 being positioned radially outwardly of the disk coils.

As will be seen best in Fig. 3, each of the spacer members 11 is of U-shape, and is comprised of a slotted upper leg 13, and a slotted lower leg 14, connected at one end by cross-piece 15. The spacer member 11 is held together despite its slotted construction by a laminated member 16 which forms the outer surface of each of the respective legs 13 and 14. The spacer members 11 may be constructed of any desired material. I have found that pressboard is a very satisfactory material for this purpose. The spacer members 11 may, if desired, be formed of one integral piece shaped to the desired form and provided with slots as indicated. However, I prefer to construct spacer 11 by joining together the various component elements which comprise the U-shaped member, as hereinbefore described. Due to its U-shaped construction, the spacer member 11 is adapted to slide over the coil winding 10 with the coil fitting between legs 13 and 14. The connecting cross pieces 15 of the respective spacer members 11 alternately abut against insulating cylinders 9 and 12, and thereby maintain coils 10 properly spaced from insulating cylinders 9 and 12, in order to obtain alternate oil blocks for proper oil distribution. As has been mentioned, the upper and lower legs 13 and 14, respectively, of the radial spacer members 11 are provided with slots for a purpose to be hereinafter described. The arrangement and construction of spacer members 11 in accordance with my invention serve to direct the flow of cooling oil through the transformer windings, as will be described hereinafter in more detail.

The cooling oil is pumped into the transformer tank through an inlet conduit 17 which passes through insulating cylinder 12. The oil may be conducted by conduit 17 into an inlet manifold 18 which is positioned in the bottom of tank 1 below the disk-shaped barrier member 19 which is, in turn, positioned beneath the lowermost disk coil. Alternatively, the inlet conduit 17 may pass through insulating cylinder 12 at a point above disk-shaped barrier member 19, in which case inlet manifold 18 would not be used. In the arrangement shown in the drawing, the oil flows upwardly or axially in the space between the outer periphery of the disk coils and the inner periphery of insulating cylinder 12. This space, in effect, serves as a continuation of manifold 18 and provides a means by which oil is distributed for cooling the plurality of disk coils. In the embodiment of my invention shown in Figs. 1 and 2, all of the disk coils are in parallel with one another with respect to the distribution of oil since they all abut on the common supply channel comprised of the space between the outer periphery of the disk coils and the inner periphery of insulating cylinder 12.

In accordance with my invention, the radial spacer members 11 between the stacked disk coils are arranged and constructed in such manner that a serpentine fluid flow is produced as the cooling oil flows circumferentially about the winding. As will best be seen in Figs. 2 and 3, all of the radial spacer members 11 are of equal length, but are alternately positioned in abutting relationship to insulating cylinder 9 and insulat-

ing cylinder 12, respectively. That is, radial spacer members 22, 24, 27, and 29 abut against insulating cylinder 9, and radial spacer members 20, 21, 23, 25, 26, and 28 abut against insulating cylinder 12. It will be seen that the serpentine oil flow characteristic provided by my spacer arrangement is due to the fact that the spacer members form oil blocks wherever they abut against an insulating cylinder, with the result that the oil in flowing past each spacer must flow around the end of the spacer which is not in abutting relation to an insulating cylinder.

It should be noted that the arrangement of radial spacer members between every set of disk coils is the same as that shown in the plan view of Fig. 2. Hence, a plurality of radial spacer members lie in the same axial plane as each of the spacer members 20-29, inclusive.

As has been mentioned, the oil rises up in the space between the inner periphery of insulating cylinder 12 and the outer periphery of the disk coils. However, this axial passage of the oil occurs substantially only in the arcuate sector between radial spacers 20 and 21 which, it will be noted, both abut against the inner periphery of insulating cylinder 12.

Due to the abutting relation between the respective radial spacers 20 and 21 and the insulating cylinder 12, the cooling oil which enters the space between any two disc coils is caused to divide into two paths. One oil flow path is in a clockwise direction around the end of spacer 20, while the other oil flow path is in a counterclockwise direction around the end of spacer 21. Due to the staggered relation of the spacer members 20-29 as just described, the oil flow in each path is of a serpentine nature, flowing radially inwardly and outwardly in accordance with the positioning of the respective radial spacer members. As indicated by the flow direction arrows, the incoming oil first flows across the radial width of the disk coil in the region between spacers 20 and 21 and then divides into two paths, passing out around the ends of spacers 20 and 21 through the space between the respective ends of spacers 20 and 21 and the outer periphery of insulating cylinder 12. One oil flow path proceeds in a clockwise direction and the other in a counterclockwise direction. It will be seen that due to the staggered arrangement of the radial spacers the oil flow in each path passes alternately radially inwardly and outwardly around the disk coil winding until it reaches the space between spacers 25 and 26.

The two oil paths which have respectively been flowing in a clockwise and counterclockwise direction, merge together again in the space between spacers 25 and 26 and the oil passes into the space between the outer periphery of the disk coils 10 and the inner periphery of insulating cylinder 12. An outlet conduit 30 is connected to the upper portion of the duct between the disk coils 10 and insulating cylinder 12 at a diametrically opposite point to the location of the inlet conduit 17. The oil which has passed across the surface of each of the respective disk coils and out into the duct between the outer periphery of the disk coils and the inner periphery of insulating cylinder 12 then passes upwardly through that duct until it reaches the outlet conduit 30. The oil passes through outlet conduit 30 to any suitable pumping device which causes the recirculation of the oil.

In accordance with my invention, in order to increase the cooling efficiency of my system, each

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of the surfaces 13 and 14 of the respective spacer members is provided with a plurality of biased slots, such as slots 31 and 32, as shown in detail in Fig. 3.

The use of the biased slots in the radial spacer members substantially eliminates what would otherwise be "dead" vortices in areas 33 and 34, indicated by dotted lines in Fig. 2, which, if allowed to remain, would reduce the cooling efficiency of the system. Areas 33 and 34 are shown in the drawing only between spacer members 22 and 23, but it will be understood that similar areas exist between each pair of spacer members.

The use of the biased slots in the spacer members also may incidentally result at certain fluid velocities in the creation of turbulence in the otherwise laminar flow pattern of the cooling fluid. This is due to the fact that the oil flowing through the slots does so at a different velocity than the oil passing around the ends of the spacer members. This different velocity of the oil passing through the biased slots sometimes results in the creation of vortices in the flow pattern of the cooling fluid. When such turbulence occurs in the fluid flow, it results in an increased efficiency of heat removal from the transformer windings since the efficiency of a liquid coolant is a function of turbulent flow.

In Fig. 4 there is shown an "exploded" view of a modified cooling arrangement in accordance with my invention in which the oil flow pattern might be termed a "series-parallel" oil flow. In this arrangement, the various disk coils are in series with one another with respect to the oil flow, rather than in the parallel relation of Figs. 1 and 2. However, in flowing across each of the respective disk coils, the oil still divides into two parallel paths, as in Figs. 1 and 2. A cutaway view of part of the winding is shown. For purposes of oil flow distribution, I divide the plurality of stacked disk coils into a plurality of flow groups, each group having at least one, and preferably more than one, disk coils in the group. These groups of disk coils are separated by disk-shaped spacer members, each of which has one peripheral notch to permit oil flow from one disk coil group to another. Thus, in Fig. 4 I show disk coils 35 and 36 which, as I have said, may represent either a single disk coil or a plurality of disk coils. A disk-shaped spacer member 37 is positioned above disk coil 35 and separates it from another disk coil above coil 36, or from an outlet pipe, neither of which is shown in the drawing. Disk-shaped spacer member 38 lies below coil 35 and separates that coil from coil 36. Spacer member 39 lies below disk coil 36 and separates that coil from another similar coil, or from an inlet pipe below it, neither of which is shown in the drawing. The diameter of each of the disk spacer members 37, 38 and 39 is such that these members make a tight fit with the internal diameter of insulating cylinder 40 so as to make improbable the leakage of any oil through the circumferential joints between the spacer disks 37, 38 and 39 and the insulating cylinder 40. Oil flow between groups of disk coils is made possible by peripheral notches 41, 42 and 43 in spacer disks 37, 38 and 39, respectively. It will be noted that adjacent spacer disks have their respective peripheral notches spaced apart by 180 degrees, with alternate spacer disks having their respective peripheral notches in the same vertical plane. Thus, notches 41 and 42 for spacer disks 37 and 38, respectively, are spaced apart 180 degrees, whereas notches 41 and 43 for spacer disks 37 and

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39, respectively, are in the same axial plane and are not angularly spaced apart.

Due to the arrangement of the notches in the spacer disks between coil groups, the oil flow through the entire winding follows a series flow pattern from one coil group to another. Thus, as the oil proceeds axially from the inlet in the lower part of the transformer casing and passes to coil 36 through notch 43 in spacer disk 39 below coil 36, the oil enters coil 36 on the left-hand side, with respect to the view shown in the drawing. It then traverses coil 36 in a left-to-right direction, thence passing upwardly to coil 35 through notch 42 in spacer member 38. The oil enters coil 35 on the right-hand side and traverses that coil in a right-to-left direction, which is just the opposite of the direction of oil flow with respect to coil 36. The oil leaves coil 35 on the left-hand side and passes through notch 41 in spacer member 37 to either a coil or outlet pipe above spacer member 37. Hence, it will be seen that the oil flow direction in adjacent winding groups is opposite, being left-to-right in one group of disk coils, and right-to-left in the adjacent group of disk coils.

As in the construction of Figs. 1, 2 and 3, the structure of Fig. 4 has a plurality of radial spacer members circumferentially spaced about each disk coil. The arrangement of these radial spacer members is similar to that shown in Figs. 1, 2, and 3, in that adjacent spacer members project alternately against a radially outer insulating cylinder 40 adjacent the outer edge of the disk coils and alternately against a radially inner insulating cylinder (not shown in the figure) adjacent the inner edge of the disk coils. The oil flow pattern with respect to each individual coil is the same as that shown in Figs. 1 and 2, the oil in entering each disk coil dividing into two paths, one path being in a clockwise direction and the other in a counterclockwise direction. The essential difference between the structure of Fig. 4 and that of Figs. 1 and 2 lies not in the oil flow pattern in the individual disk windings, since that is the same in Figs. 1-4 inclusive, but rather in the manner of distributing oil from one coil or group of coils to another coil or group of coils. This distribution difference, as has been described hereinbefore, is accomplished by using notched spacer disk members such as 37, 38 and 39.

There is shown in Fig. 5 a further modification of my invention which differs principally from the construction shown in Fig. 4 in that the oil flow around each disk coil is entirely a series oil flow. That is, the various disk coils are in series with one another with respect to the oil flow, as in Fig. 4, and, additionally, the oil flows circumferentially around each respective disk coil in only one path, rather than splitting into two parallel paths as in the arrangements of Figs. 1-4.

In Fig. 5 there are shown two disk coils 44 and 45, each of which may represent a single disk coil, as shown, or a group of disk coils. Spacer disk 46 is positioned above coil 44 and separates it from a similar disk coil or from an outlet pipe, neither of which is shown in the drawing. Spacer disk 47 is positioned between disk coils 44 and 45 and serves to separate these two coils or groups of coils. Spacer disk 48 is positioned below disk coil 45 and separates it from a similar disk coil or group of coils, or from an inlet pipe below spacer disk 48. Each of the spacer disks has a notch cut at one place

on its outer periphery in order to permit flow of oil from one disk coil or group of disk coils to another disk coil or group of disk coils. Thus, spacer disk 46 is provided with notch 49 and spacer disks 47 and 48 are provided with notches 50 and 51, respectively.

Each of the disk coils in Fig. 5 is provided with a plurality of radial spacer members similar to those shown in Figs. 1-4 inclusive. Alternate spacer members are positioned against an outer insulating cylinder 52 and against a radially inner insulating cylinder (not shown in the figure) which are adjacent the radially outer and inner circumferences of the stacked disk coils, respectively. The principal difference between the arrangement of the radial spacer members of Fig. 5 and the arrangement of the radial spacer members shown in Figs. 1-4 inclusive, is that blocking spacer members 53 and 54 are used in such manner as to permit oil flow in only one path across each disk coil, rather than dividing into parallel paths as in the constructions of Figs. 1-4. One of the spacer members for each disk coil is made longer than any of the others and extends flush with both the radially outer insulating cylinder 52 and also with the radially inner insulating cylinder (not shown). Thus, radial spacer members 53 and 54 of disk coils 44 and 45, respectively, extend flush with both the radially outer insulating cylinder 52 and the radially inner insulating cylinder. Also, it should be noted that radial spacers 53 and 54 are not provided with biased slots as in the case of the other radial spacer members. The effect of the construction of radial spacer members 53 and 54 is to act as a complete block or barrier to oil flow in a given direction. Due to this construction, the oil flow across any particular disk coil is constrained to flow in a continuous path entirely around the periphery of the disk coil, flowing in a serpentine manner around the spacer members in accordance with the flow direction arrows shown in the drawing, and passing out through the notches 49 and 50 in spacer disks 46 and 47, respectively.

Thus, considering the direction of oil flow shown in Fig. 5, it will be seen that the oil passes upwardly through notch 51 in lower spacer disk 48 and enters disk coil 45 in the region between spacers 54 and 56. Due to the fact that spacer 54 extends flush with both the radially inner and outer insulating cylinders, as hereinbefore described, the oil can flow in only one direction, in this case a clockwise direction. The oil proceeds in a clockwise direction entirely the way around disk coil 45 until it reaches the right-hand edge of spacer member 54, which acts as a block to prevent further fluid flow in that direction. The oil then passes upwardly through notch 50 in spacer disk 47 which lies directly above disk coil 45, with notch 50 being positioned above the region between spacer 54 and spacer 57. The oil enters disk 44 in the region between spacers 53 and 58. Since spacer 53 extends flush with both the radially inner and outer insulating cylinders, as hereinbefore described, the oil can flow in only one direction, in this case a counterclockwise direction. The oil flows in a counterclockwise direction around disk coil 44, winding in a serpentine manner about the ends of the radial spacer members, and completely encircles the disk 44 until it reaches the left-hand edge of spacer member 53 which blocks further fluid flow in that direction. The oil then flows up through notch 49 of spacer disk 46, notch

49 being positioned directly above the region between the left-hand edge of radial spacer 53 and radial spacer member 59, to the left of radial spacer 53.

It will be seen that the blocking radial spacer members 53 and 54 are in superposed relation, and all of the other similar blocking radial spacer members for the other disk coils are in superposed relation to spacer members 53 and 54. The notches in the respective spacer disk members, such as notches 50 and 51, are all positioned alternately to the left and to the right of the superposed blocking radial spacer members.

Thus, it can be seen that with the cooling ducts which I provide by means of my radial spacing members and the fluid flow pattern which is induced by the arrangement of those spacers and by their slotted construction, I have provided an efficient and economical construction for cooling a transformer structure by means of the forced flow of a liquid coolant.

While there have been shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that various changes and modifications can be made therein without departing from the invention and, therefore, it is aimed in 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. In stationary electrical induction apparatus of the type having a winding which includes a plurality of spirally-wound disk coils stacked in superposed relation, means for directing flow of a cooling liquid between said coils in a generally circumferential direction, comprising a plurality of radial spacer members positioned between adjacent coils to maintain a duct between said coils, said radial spacer members extending radially across the adjacent surfaces of the respective disk coils between which they are positioned and being circumferentially displaced from each other around substantially the entire circumference of said disk coils, a first insulating cylinder spaced radially inwardly of said disk coils, a second insulating cylinder spaced radially outwardly of said disk coils, said radial spacer members abutting alternately against said first cylinder and said second cylinder, each of said spacer members being spaced radially from the one of said insulating cylinders which it does not abut, said cooling liquid flowing in a generally circumferential direction between said disk coils alternately radially inwardly and outwardly, flowing around the end of said spacer members through the space between the end of each of said spacer members and the insulating cylinder which it does not abut, each of said spacer members having at least one transverse slot therein to permit passage therethrough of a relatively small portion of said liquid in substantially the same flow direction as the main body of said liquid passing around the end of said spacer, said plurality of disk coils being divided into a plurality of groups for cooling purposes, each of said groups having at least one disk coil, with disk-shaped spacer members separating said coil groups, each of said disk-shaped spacer members having an aperture to permit passage of cooling fluid from one coil group to another, said coil groups being in series with each other with respect to said fluid flow.

2. In stationary electrical induction apparatus of the type having a winding which includes a plurality of spirally-wound disk coils stacked in

superposed relation, means for directing flow of a cooling liquid between said coils in a generally circumferential direction, comprising a plurality of radial spacer members positioned between adjacent coils to maintain a duct between said coils, said radial spacer members extending radially across the adjacent surfaces of the respective disk coils between which they are positioned and being circumferentially displaced from each other around substantially the entire circumference of said disk coils, a first insulating cylinder spaced radially inwardly of said disk coils, a second insulating cylinder spaced radially outwardly of said disk coils, all except one of said radial spacer members abutting alternately said first and second cylinders, said one radial spacer member abutting both of said cylinders, said plurality of disk coils being divided into a plurality of groups for cooling purposes, each of said groups having at least one disk coil, with disk-shaped spacer members separating said coil groups, each of said disk-shaped spacer members having an aperture to permit passage of cooling fluid from one coil group to another, said coil groups being in series with each other with respect to said fluid flow, said cooling liquid within a given coil group flowing in a generally circumferential direction between said disk coils alternately radially inwardly and outwardly, flowing around the end of each of said radial spacer members until it reaches said radial spacer member which abuts both of said cylinders, the cooling liquid then passing to an adjacent group of disk coils through an aperture in one of said disk-shaped spacer members, each of said radial spacer members except the spacer member which abuts both of said cylinders having at least one transverse slot therein to permit passage thereof of a relatively small portion of said fluid in substantially the same flow direction as the main body of said fluid passing around the end of said spacer.

3. In stationary electrical induction apparatus of the type having a winding which includes a plurality of spirally-wound disk coils stacked in superposed relation, means for directing flow of a cooling liquid between said coils in a generally circumferential direction comprising a plurality of radial spacer members positioned between adjacent coils to maintain a duct between said coils, said spacer members extending radially across the adjacent surfaces of the respective disk coils between which they are positioned and being circumferentially displaced from each other around substantially the entire circumference of said disk coils, a concentric cylindrical barrier member positioned radially inwardly and a concentric cylindrical barrier member positioned radially outwardly of said coils, each of said radial spacer members having one end in abutting relation to one of said cylindrical barrier members with the other end of each of said radial spacer members being radially displaced from the other of said cylindrical barrier members, said radial spacer members being arranged so as to alternately abut said radially inner and said radially outer barrier members, the greater portion of said cooling liquid passing in a generally circumferential direction around said ends of said radial spacer members which are displaced from said barrier members, each of said radial spacer members having at least one transverse slot therein to permit passage thereof of a relatively small portion of said cooling liquid, said plurality of disk coils being divided into a plurality of groups for cooling purposes, each of said groups having

at least one disk coil, with disk-shaped spacer members separating said coil groups, each of said disk-shaped spacer members having an aperture to permit passage of cooling fluid from one coil group to another.

4. In a stationary electrical induction apparatus of the type having a winding which includes a plurality of spirally wound disk coils stacked in superposed relation, means for directing flow of a cooling liquid between said coils in a generally circumferential direction comprising a plurality of radial spacer members positioned between pairs of adjacent coils to maintain a duct between said coils, said radial spacer members extending radially across the adjacent surfaces of the respective disk coils between which they are positioned and being circumferentially displaced from each other around substantially the entire circumference of said coils, a first insulating cylinder spaced radially inwardly of said disk coils, a second insulating cylinder spaced radially outwardly of said disk coils, said radial spacer members abutting alternately against said first cylinder and said second cylinder, each of said spacer members being spaced radially from the one of said insulating cylinders which it does not abut, said cooling liquid flowing in a generally circumferential direction between said pairs of disk coils alternately radially inwardly and outwardly, flowing around the end of said spacer members through the space between the end of each of said spacer members and the insulating cylinder which it does not abut, said disk coils being divided into a plurality of groups for cooling purposes, each of said groups having at least one disk coil, with disk-shaped spacer members axially separating said coil groups, each of said disk-shaped spacer members having an aperture to permit passage of cooling fluid from one coil group to another, said coil groups being in series with each other with respect to said fluid flow.

5. In a stationary electrical induction apparatus of the type having a winding which includes a plurality of spirally wound disk coils stacked in superposed relation, means for directing flow of a cooling liquid between said coils in a generally circumferential direction comprising a plurality of radial spacer members positioned between adjacent coils to maintain a duct between said coils, said radial spacer members extending radially across the adjacent surfaces of the respective disk coils between which they are positioned and being circumferentially displaced from each other around substantially the entire circumference of said respective pairs of disk coils, a first insulating cylinder spaced radially inwardly of said disk coils, a second insulating cylinder spaced radially outwardly of said disk coils, all except one of said radial spacer members abutting alternately said first and second cylinders, said one radial spacer member abutting both of said cylinders, said plurality of disk coils being divided into a plurality of coil groups for cooling purposes, each of said groups having at least one disk coil, with disk-shaped spacer members separating said coil groups, each of said disk-shaped spacer members having an aperture to permit passage of cooling fluid from one coil group to another, said coil groups being in series with each other with respect to said liquid flow, said cooling liquid within a given coil group flowing in a generally circumferential direction between said disk coils alternately radially inwardly and outwardly, flowing around the end of each of said radial spacer members until it reaches said radial spacer mem-

ber which abuts both of said cylinders, said cooling liquid then passing to an adjacent group of disk coils through an aperture in one of said disk-shaped spacer members.

6. In a stationary electrical induction apparatus of the type having a winding which includes a plurality of spirally-wound disk coils stacked in superposed relation, means for directing flow of a cooling liquid between said coils in a generally circumferential direction comprising a plurality of radial spacer members positioned between adjacent coils to maintain a duct between said coils, said radial spacer members extending radially across the adjacent surfaces of the respective disk coils between which they are positioned and being circumferentially displaced from each other around substantially the entire circumference of said respective pairs of disk coils, a concentric cylindrical barrier member positioned radially inwardly and a concentric cylindrical barrier member positioned radially outwardly of said coils, each of said radial spacer members having one end in abutting relation to one of said cylindrical barrier members with the other end of each of said radial spacer members being radially displaced from the other of said cylindrical barrier members, said radial spacer members being arranged so as to alternately abut said radially inner and said radially outer barrier members, said cooling liquid passing in a generally circumferential direction around said ends of said radial spacer members which are displaced from said barrier members, said plurality of disk coils being divided into a plurality of coil groups for cooling purposes, each of said groups having at least one disk coil, with disk-shaped spacer members axially separating said coil groups, each of said disk-shaped spacer members having an aperture to permit passage of cooling fluid from one coil group to another.

7. In a stationary electrical induction apparatus of the type having a winding which includes a plurality of spirally-wound disk coils stacked in superposed relation, means for directing flow of a cooling liquid between said coils in a generally circumferential direction comprising a plurality of radial spacer members positioned between adjacent coils to maintain a duct between said coils, said radial spacer members ex-

tending radially across the adjacent surfaces of the respective disk coils between which they are positioned and being circumferentially displaced from each other around substantially the entire circumference of said disk coils, a concentric cylindrical barrier member positioned radially inwardly and a concentric cylindrical barrier member positioned radially outwardly of said coils, each of said radial spacer members having one end in abutting relation to one of the cylindrical barrier members with the other end of each of said radial spacer members being radially displaced from the other of said cylindrical barrier members, said radial spacer members being arranged so as to alternately abut said radially inner and said radially outer barrier members, said cooling liquid passing in a generally circumferential direction around said ends of said radial spacer members which are displaced from said barrier members, said disk coils being divided into a plurality of coil groups for cooling purposes, each of said coil groups having at least one disk coil, with disk-shaped spacer members axially separating said coil groups, each of said disk-shaped spacer members having an aperture to permit passage of cooling liquid from one coil group to another, the entrance and exit apertures for the cooling liquid for any given coil group being positioned substantially diametrically opposite one another, the cooling liquid for any given coil group flowing from the entrance aperture to the exit aperture for that coil group in two liquid flow paths which are in parallel liquid flow relation with respect to each other.

WILFRED J. BILODEAU.

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