

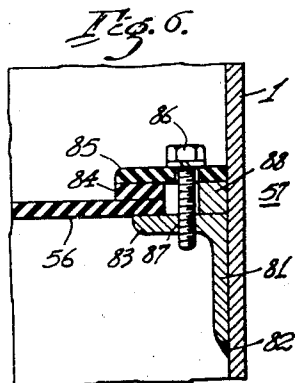
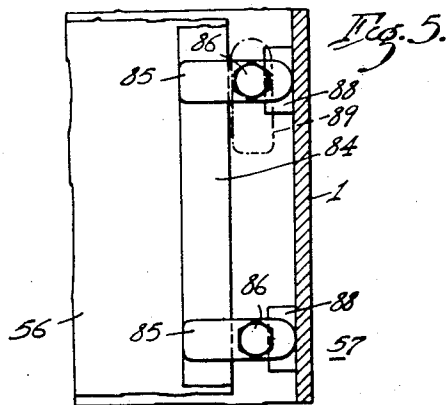
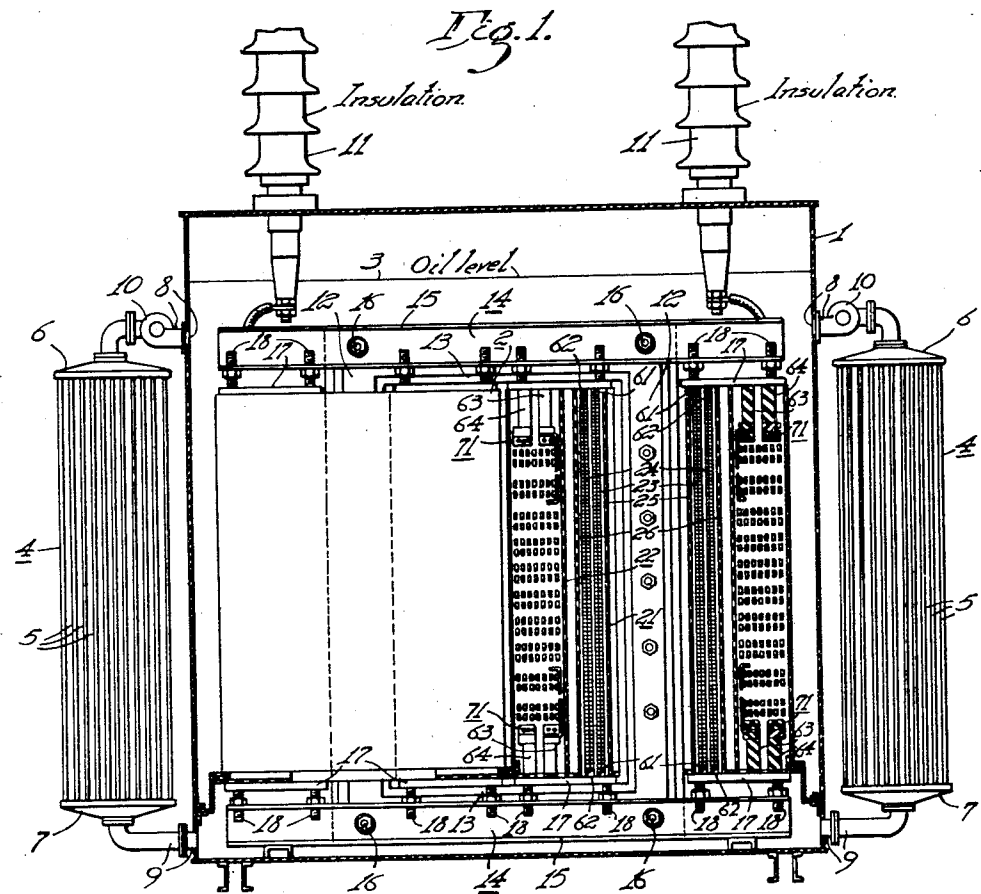
Nov. 16, 1948.

F. D. FIELDER
ELECTRICAL APPARATUS

2,454,147

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2 Sheets-Sheet 1



WITNESSES:
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Nov. 16, 1948.

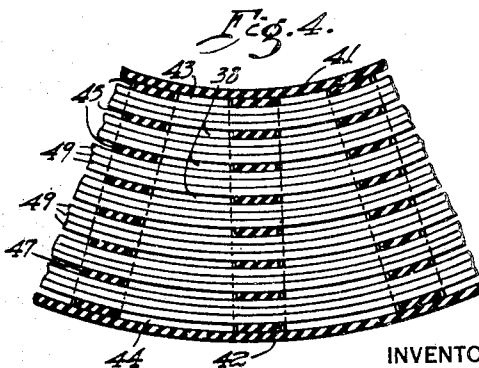
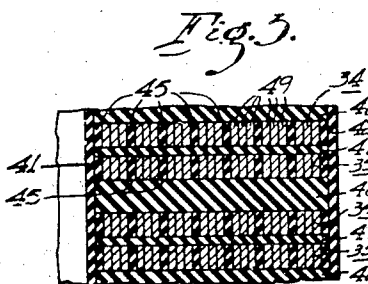
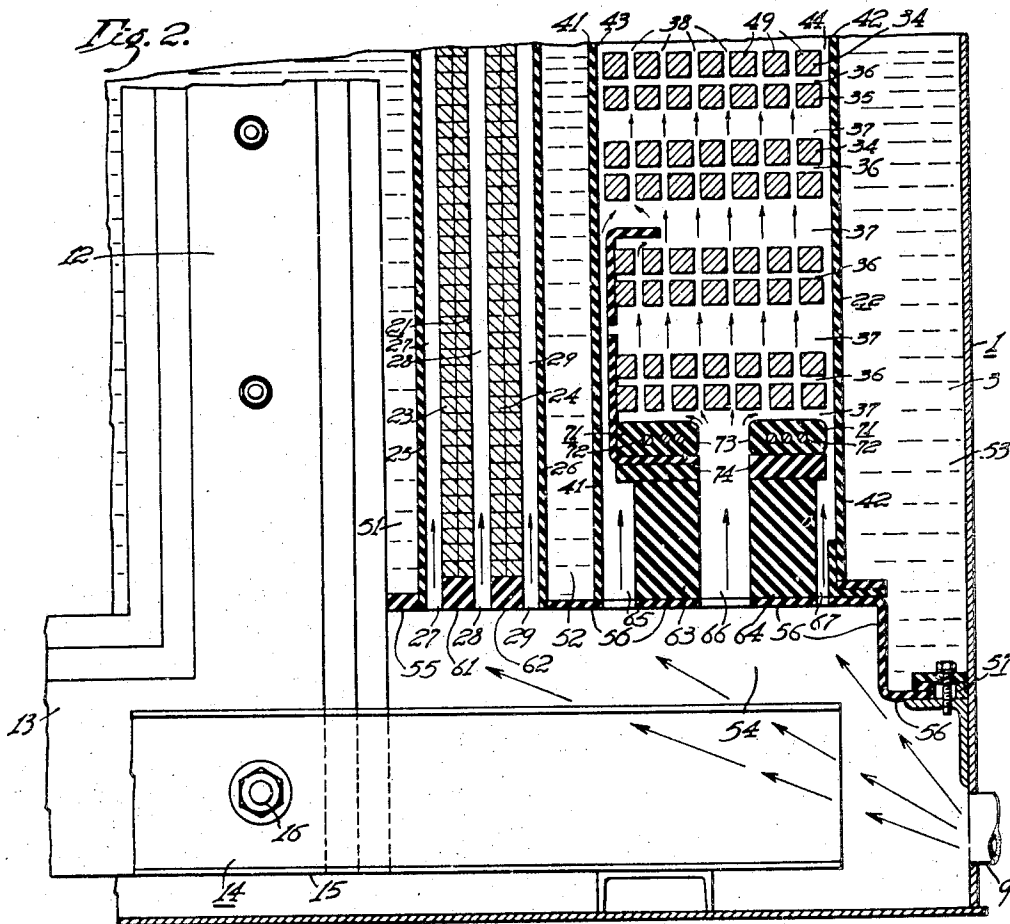
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2 Sheets-Sheet 2



WITNESSES:

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2,454,147

ELECTRICAL APPARATUS

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My invention relates to electrical apparatus, such as transformers, and particularly to the arrangement of the parts of the apparatus for increasing the efficiency of cooling the apparatus. The invention is illustrated as applied to a core form transformer structure which is cooled by a liquid cooling and insulating medium, such as oil, in a cooling system in which the circulation of the cooling liquid is forced by pumping.

It is common practice to immerse electrical induction apparatus, such as transformers, in a cooling and insulating liquid, such as oil, and to provide cooling ducts through which the liquid passes along the heated parts of the apparatus to absorb heat therefrom, and to provide for circulating such cooling medium to bring it into contact with the transformer tank wall, or with the walls of radiators or coolers connected to the tank wall through the surfaces of which heat is communicated to the outside air, and the liquid is thus cooled. The cooling medium thus flows downwardly along the radiator or tank wall surfaces and upwardly through the apparatus to be cooled, absorbing heat from the apparatus and conveying it through the radiator and tank walls to the surrounding medium, such as air.

It often occurs in the operation of electrical apparatus, such as transformers, that the natural circulation of the cooling and insulating liquid through the transformer tank and radiators by thermal action alone is inadequate to dissipate enough heat to keep the transformer sufficiently cool for safe operation, particularly during peak loads.

The heat dissipated by the windings and core of a transformer is a function of the load on the transformer. In a liquid-cooled transformer having a radiator type cooling system, the heat is first conveyed from the conductors of the windings, and from the core, to the cooling liquid, and then as the liquid circulates through the system the heat passes from the liquid through the walls of the transformer tank and the radiator walls to the surrounding medium, which is usually air.

It has been found desirable to operate the copper of the transformer windings at or below a certain predetermined temperature. The greater the capacity of the cooling system for dissipating the heat generated by the flow of current through the transformer windings, the greater is the load that may be safely carried by a given transformer.

In a transformer cooled by natural convection alone, where there is no forced flow of the cooling medium, the circulation of the cooling liquid is comparatively slow through the cooling ducts pro-

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vided between the winding coils. This results in a large difference in temperature between the average temperature of the copper in the winding coil of the transformer and the average temperature of the cooling fluid. If the rate of flow of the cooling liquid can be increased to the point where there is no stationary film of oil remaining on the coil surface, the temperature gradient between the coil and the oil will be greatly reduced.

In accordance with my invention, the transformer coils are so constructed as to give turbulent oil flow along the contacting surfaces between the copper conductors to be cooled, and means is provided to give high velocity flow along the surfaces, resulting in low temperature gradient between the conductors and the oil or similar cooling liquid.

It is an object of the invention to provide means so organized as to effect a considerable increase in the cooling capacity of the apparatus without increasing the amount of critical material used.

It is a further object of the invention to provide a plurality of passageways distributed between the heated conductors of the windings to provide many contact surfaces along which the cooling medium may contact the parts to be cooled.

It is a further object of the invention to provide barriers so arranged as to more effectively guide the cooling fluid along the surfaces from which heat is communicated to that fluid.

Other objects of the invention will be apparent from the following description of a preferred embodiment of the invention taken in connection with the accompanying drawings, in which,

Figure 1 is a vertical view partly in section of a transformer constructed in accordance with the invention;

Fig. 2 is an enlarged view of a portion of the structure shown in Fig. 1, omitting certain parts;

Figs. 3 and 4 are vertical and horizontal sectional views, respectively, showing portions of the high voltage winding of the transformer; and

Figs. 5 and 6 are detail views.

Referring to the drawings, Fig. 1 illustrates a transformer casing or tank 1, enclosing a transformer core and coil assembly 2 which is normally immersed in a cooling and insulating liquid 3, to an elevation sufficiently high to permit circulation through radiator elements 4, connected at top and bottom to the tank 1. As illustrated, the radiators include vertical cooler members 5 extending between upper and lower headers 6 and 7, and connected through suitable conduits 8 and 9, to the interior of the tank 1 adjacent the top and bottom thereof, respectively. Pumping means 10 are shown for effecting a forced flow of the

cooling liquid through the circulating path, including the transformer tank and radiators. High voltage bushings 11 are shown mounted on the cover of the tank through which circuit conductors extend and connect to the conductors of the high voltage winding of the apparatus.

A core form transformer structure is shown, the core of which is provided with two vertical winding leg portions 12, connected at the top and bottom by yoke portions 13 which complete the magnetic circuit path. End frames 14 are provided at the top and bottom of the core structure and consist essentially of channels 15, extending along the opposite surfaces of the laminations, comprising the yoke portions of the core and held together by bolts 16, extending through the core in a well known manner. Pressure plates 17 are provided, mounted on the end frames and adapted to support the transformer windings therebetween. The pressure plates are adjustably supported from the end frames by means of bolts 18 to readily adjust the pressure brought against the ends of the windings supporting therebetween.

A low voltage winding assembly 21 and a high voltage winding assembly 22 are provided about each of the vertical winding legs 12 of the core and are shown in section in Fig. 1. A portion of this section is enlarged in Fig. 2 to more clearly disclose the parts thereof and their relative positions.

Referring particularly to Fig. 2, the low voltage winding assembly 21, which is positioned closest to the winding leg 12, comprises two cylindrical coils 23 and 24 and two cylindrical barriers 25 and 26 of insulating material positioned on the inside and outside, respectively, of the conductor turns of the winding comprising the coils 23 and 24. The coils and barriers are spaced apart to provide vertical annular ducts 27, 28, and 29 adjacent the surfaces of the cylindrical coils 23 and 24 to provide for the relatively rapid movement of insulating fluid upwardly along the surfaces of the coils.

The outer high voltage winding assembly 22 comprises a plurality of flat disc or pancake type coils shown in pairs 34 and 35 and spaced apart vertically to provide radial or horizontal ducts 36 and 37 for the flow of the cooling liquid. Groups of conductor strands (shown in outline in Fig. 2) are separated to provide vertical ducts 38 in general alignment through the stack of disc-type coils 34 and 35 to provide annular vertical passageways through which the cooling oil may flow upwardly between the turns of the winding conductors of the coils 23 and 24. The general direction of flow of the cooling liquid is shown by the arrows in Fig. 2. The outer high voltage winding assembly 22 includes an inner cylindrical barrier 41 and an outer cylindrical barrier 42, spaced sufficiently from the inner surface and from the outer surface of the stack of coils 34 and 35 forming the winding 22 to provide vertical oil ducts 43 and 44, respectively, adjacent the inner and outer periphery of the winding 22.

In order to more clearly show the path of flow of the cooling liquid, the spacer members for holding the conductor turns and cylindrical barriers in proper spaced relation are omitted in Fig. 2.

Referring to Figs. 3 and 4, it will be noted that vertical spacer members 45 are provided for spacing the conductor turns in the coils 34 and 35 to provide vertical ducts 38. As shown in Figs. 3 and 4, three conductor turns 49 comprise a group

of winding turns between each of the spacers 45. For the sake of convenience in illustrating, the group is shown as a unit in Fig. 2 instead of identifying the individual turns. It will, of course, be appreciated that any desired number of turns may be included in such a group. As shown in Figs. 3 and 4, radial spacers 47 and 48 are provided extending radially from the cylindrical barrier 41 to the barrier 42 between successive disc-type coils 34 and 35, comprising a stack of coils forming the winding 22.

It will be noted that there is a space 51 provided between the winding leg 12 of the core structure and the low voltage winding 21, a space 52 between the low voltage assembly 21 and the high voltage assembly 22, and a space 53 between the high voltage winding 22 and the tank wall 1 which several spaces are required in order to give the proper insulating strength through the liquid medium 3 in which the apparatus is immersed. In order to provide for a more rapid flow of the cooling medium along the surfaces of the winding conductors to be cooled, barriers of insulating material, such as pressboard, are positioned across the bottom of the windings to prevent the circulation of oil or a similar cooling and insulating medium from the space 54 beneath the coils upwardly through the spaces 51, 52, and 53, and to require the circulating fluid to pass through the several vertical ducts 27, 28, and 29 in the low voltage winding assembly and the vertical ducts 30, 43, and 44 in the high voltage winding assembly. Barrier 55 is shown between the core winding leg 12 and the cylindrical barrier 25, outlining the inner wall of the low voltage winding assembly. A horizontal barrier 56 is shown extending from the cylindrical barrier 26, forming the outer periphery of the low voltage winding assembly 21 and passing beneath the cylindrical barriers 41 and 42 of the high voltage winding assembly 22 to a barrier seal joint 57 along the inner wall of the casing 1. These horizontal barriers 55 and 56 restrict the free flow of the insulating and cooling medium so as to cause most of it to flow through the several ducts closely adjacent to the conductor surfaces to be cooled resulting in a more rapid movement of this liquid medium in those areas required to carry the heat from the copper conductors. The barrier 55 is placed about the winding leg loosely enough to permit some flow of the cooling medium about the core leg to cool it, but the greater part of the cooling liquid goes through the ducts adjacent the winding conductors.

In order to more clearly illustrate the passageways and ducts for directing the flow of the cooling and insulating liquid medium, the pressure plates 17, shown in Fig. 1 are omitted from Fig. 2. For the purpose of supporting the ends of the windings from the pressure plates 17, pressure collars of insulating material are provided, two such collars 61 and 62 being shown adjacent the opposite ends of the cylindrical coils 23 and 24. These collars are annular in shape, following the end surface of the cylindrical coils and forming stiffening members between the pressure plates and the coil ends to support the coils. Similar collars 63 and 64 are provided for the high voltage winding, these collars being higher because of the greater insulating strength required. The collars 63 and 64 are spaced to provide the passageways 65, 66, and 67 through which the cooling and insulating medium, such as oil, is supplied to the vertical ducts 43, 38, and 44 previously described. Static plate elements 71 are

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provided, comprising essentially a plurality of turns of wire 72 embedded in insulating blocks 73 and supported by blocks 74 of insulating material positioned between the static plate elements 71 and the pressure collars 63 and 64. It will be appreciated that the radial spacers 47 and 48 shown in Fig. 3 are positioned between the static plate elements 71 and the series of flat coils 34 and 35 comprising the coil stack of the high voltage winding 22 at the required elevations up to similar static plate elements 71 at the upper end of the winding.

In order to seal the barrier 56 against the tank wall 1 and at the same time to provide for readily removing the transformer core and coil assembly from the tank, a joint 57 between the outer periphery of the barrier 56 of the tank wall is provided. The structure of this joint is more clearly shown in Figs. 5 and 6 and comprises a steel angle 81 welded as at 82 to the tank wall 1 and having an inwardly extending horizontal flange 83 adapted to receive and support the outer rim of the barrier 56. This steel angle extends continuously along the inner surface of the tank wall forming an annular support for the rim of the barrier 56. A stiffener 84 of insulating material, such as Micarta, is provided along the rim of the barrier 56 and a series of micarta clamps 85 are provided, extending inwardly from the tank wall and adapted to grip the stiffener member 84 and the rim of the barrier 56 between the clamps 85 and the rim of the angle iron 81. For this purpose, bolts 86 are provided at spaced intervals along the flange 83 for holding clamps 85 in the positions shown in full lines in Figs. 5 and 6, the lower end of the bolts being screw threaded into the flange 83 of the angle iron at 87. The location of these bolts is such that a tool having a long handle may be readily extended down along the inner wall of the tank to loosen or tighten the bolts 86. Stop members 88 are positioned (as shown) to space the inner end of the clamping members 85 at a convenient elevation. When it is desired to remove the core and coil assembly from the tank, the bolts 86 are loosened and the clamping members 85 turned through 90° to the position shown in dotted lines 89 in Fig. 5, thus permitting the barrier 56 and the remaining parts of the core and coil assembly to be moved vertically from the tank.

The invention is illustrated with respect to a transformer having cylindrical low voltage winding coils and pancake or disc type high voltage winding coils. It will be appreciated however that other groupings of the windings may be made within the spirit of the invention.

Since modifications in the apparatus illustrated and described, and which may be made within the spirit of the invention, will occur to those skilled in the art, I do not wish to be limited otherwise than by the scope of the appended claims.

I claim as my invention:

1. In an electrical transformer, in combination, a core and coil assembly comprising a magnetic core structure having a vertical winding leg, a low voltage winding assembly spaced from and surrounding the winding leg of the core, the low voltage winding assembly including two cylindrical barriers of insulating material positioned in spaced relation from the low voltage winding on the inside and on the outside thereof, respectively, a high voltage winding assembly spaced from and surrounding the low voltage winding assembly and comprising a plurality of flat disc-

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type coils spaced apart to provide space for the circulation of cooling and insulating liquid therebetween, each coil having a plurality of turns of conductor strands, the conductor strands being spaced radially apart at intervals to provide a plurality of annular passageways in vertical alignment through the coils to permit cooling liquid to pass vertically therethrough, the high voltage winding assembly including two cylindrical barriers of insulating material positioned in spaced relation from the high voltage winding coils on the inside and outside thereof, respectively, and a barrier of insulating material below the bottom of the coils of the windings and continuing to the tank wall to prevent cooling liquid from passing upwardly in the space between the winding leg of the core and the low voltage winding assembly, between the high voltage winding assembly and the tank wall, and in the space between the high-voltage winding assembly and the low-voltage winding assembly, the barrier being provided with openings therethrough positioned to permit the flow of cooling liquid upwardly through the cooling passageways within the winding assemblies adjacent the conductor turns to be cooled.

2. In an electrical transformer, in combination, a core and coil assembly comprising a magnetic core structure having a vertical winding leg, a low voltage winding assembly spaced from and surrounding the winding leg of the core, the low voltage winding assembly including two cylindrical barriers of insulating material positioned in spaced relation from the low voltage winding on the inside and on the outside thereof, respectively, a high voltage winding assembly spaced from and surrounding the low voltage winding assembly and comprising a plurality of flat disc-type coils spaced apart to provide space for the circulation of cooling and insulating liquid therebetween, each coil having a plurality of turns of conductor strands, the conductor strands being spaced radially apart at intervals to provide a plurality of annular passageways through the coils to permit cooling liquid to pass vertically therethrough, the high voltage winding assembly including two cylindrical barriers of insulating material positioned in spaced relation from the high voltage winding coils on the inside and outside thereof, respectively, and a barrier of insulating material below the bottom of the coils of the windings and continuing to the tank wall to prevent cooling liquid from passing upwardly in the space between the high voltage winding assembly and the tank wall, and in the space between the high-voltage winding assembly and the low-voltage winding assembly, the barrier being provided with openings therethrough positioned to permit the flow of cooling liquid upwardly through the cooling passageways within the winding assemblies adjacent the conductor turns to be cooled, and a barrier in the space between the winding leg of the core and the low voltage winding assembly for limiting the flow of cooling and insulating liquid between the winding leg of the core and the low voltage winding assembly.

3. In an electrical transformer, in combination, a core and coil assembly comprising a magnetic core structure having a vertical winding leg, a low voltage winding assembly spaced from and surrounding the winding leg of the core, the low voltage winding assembly including two cylindrical barriers of insulating material positioned in spaced relation from the low voltage winding on

the inside and on the outside thereof, respectively, a high voltage winding assembly spaced from and surrounding the low voltage winding assembly and comprising a plurality of flat disc-type coils spaced apart to provide space for the circulation of cooling and insulating liquid therebetween, each coil having a plurality of turns of conductor strands, the conductor strands being spaced radially apart at intervals to provide a plurality of annular passageways through the coils to permit cooling liquid to pass vertically therethrough, the high voltage winding assembly including two cylindrical barriers of insulating material positioned in spaced relation from the high voltage winding coils on the inside and outside thereof, respectively, and barriers of insulating material below the bottom of the coils arranged to guide the flow of cooling and insulating liquid upwardly against the bottom of the high voltage and low voltage coils and upwardly between the cylindrical barriers outlining the low voltage winding assembly and between the cylindrical barriers outlining the high voltage winding assembly, and for limiting the flow of the cooling and insulating liquid in the spaces between the winding leg of the core and the low voltage winding assembly, between the low voltage winding assembly and the high voltage winding assembly, and surrounding the high voltage winding assembly.

4. In an electrical transformer, in combination, a casing, an insulating and cooling liquid in the casing, a core and coil assembly within the casing immersed in the liquid and comprising a magnetic core structure having a vertical winding leg, and upper and lower end frames for supporting the core and coil structure, a low voltage winding assembly spaced from and surrounding the winding leg of the core and supported between the end frames, a high voltage winding assembly spaced from and surrounding the low voltage winding assembly and supported between the end frames, the conductor turns comprising the windings in both the low voltage winding and the high voltage winding being spaced to provide vertical ducts for the flow of the cooling and insulating liquid between the outer and inner periphery of the winding, the low voltage winding assembly and the high voltage winding assembly each including two cylindrical barriers spaced slightly from the outer and inner surfaces of the winding turns respectively forming narrow ducts along the surfaces of the winding for guiding the flow of cooling and insulating liquid adjacent the conductor turns, and barriers

for blocking the upward flow of the cooling and insulating liquid from the space below the windings to the space above the windings except through the above-defined ducts.

5. In an electrical transformer, in combination, a casing, an insulating and cooling liquid in the casing, a core and coil assembly within the casing immersed in the liquid and comprising a magnetic core structure having a vertical winding leg, and upper and lower end frames for supporting the core and coil structure, a low voltage winding assembly spaced from and surrounding the winding leg of the core and supported between the end frames, a high voltage winding assembly spaced from and surrounding the low voltage winding assembly and supported between the end frames, the conductor turns comprising the windings in both the low voltage winding and the high voltage winding being spaced to provide vertical ducts for the flow of the cooling and insulating liquid between the outer and inner periphery of the winding, the low voltage winding assembly and the high voltage winding assembly each including two cylindrical barriers spaced slightly from the outer and inner surfaces of the winding turns respectively, forming narrow ducts along the surfaces of the winding for guiding the flow of cooling and insulating liquid adjacent the conductor turns, and barriers for blocking the upward flow of the cooling and insulating liquid from the space below the windings to the space above the windings except through the above defined ducts, and a plurality of spaced annular collars of insulating material positioned between the opposite ends of the high voltage winding and the end frames for supporting the winding and providing annular passageways for directing the flow of cooling liquid through the ducts adjacent the winding turns.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,304,257	Brand	May 20, 1919
1,489,303	Bingay	Apr. 8, 1924
1,703,410	Smith	Feb. 26, 1929
1,731,867	Rice	Oct. 15, 1929
1,747,953	Roothaan	Feb. 18, 1930
1,955,313	Sauer	Apr. 17, 1934
2,347,989	Burnham	May 2, 1944