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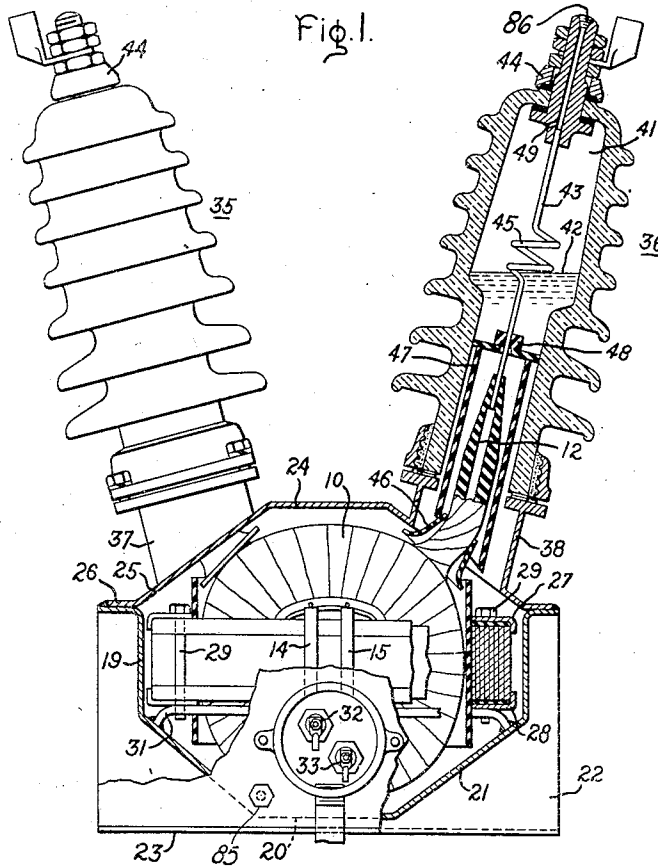
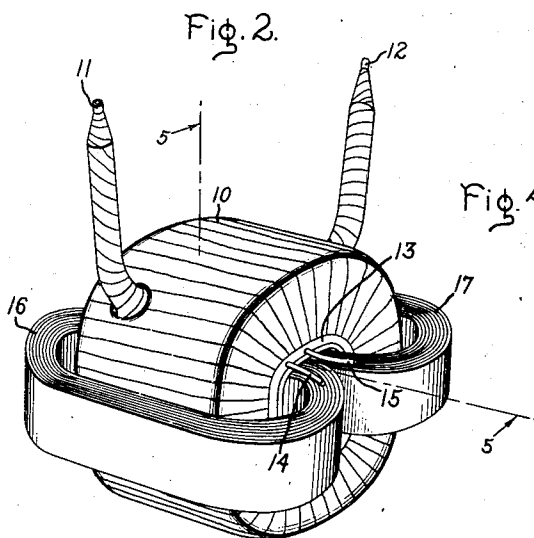
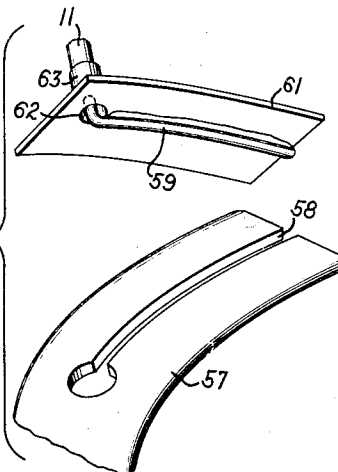
G. CAMILLI

**2,297,606**

ELECTRIC APPARATUS

Filed March 26, 1941

2 Sheets-Sheet 1



Inventor:  
 Guglielmo Camilli,  
 by *Harry E. Denham*  
 His Attorney.

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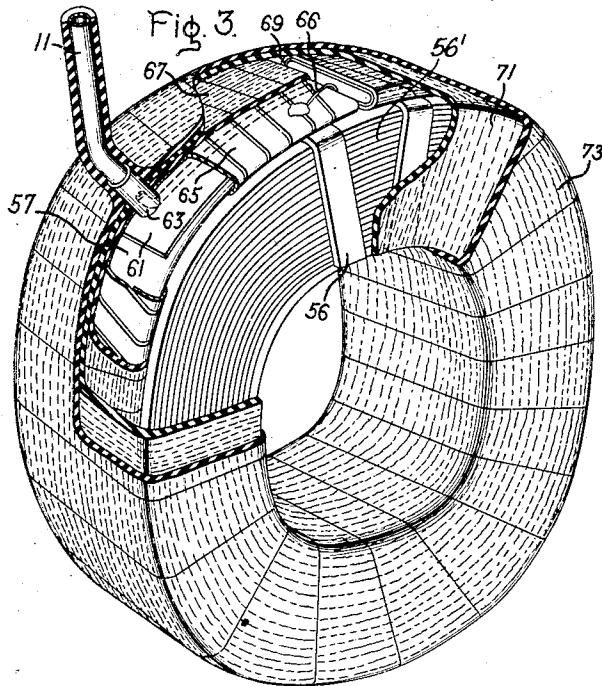
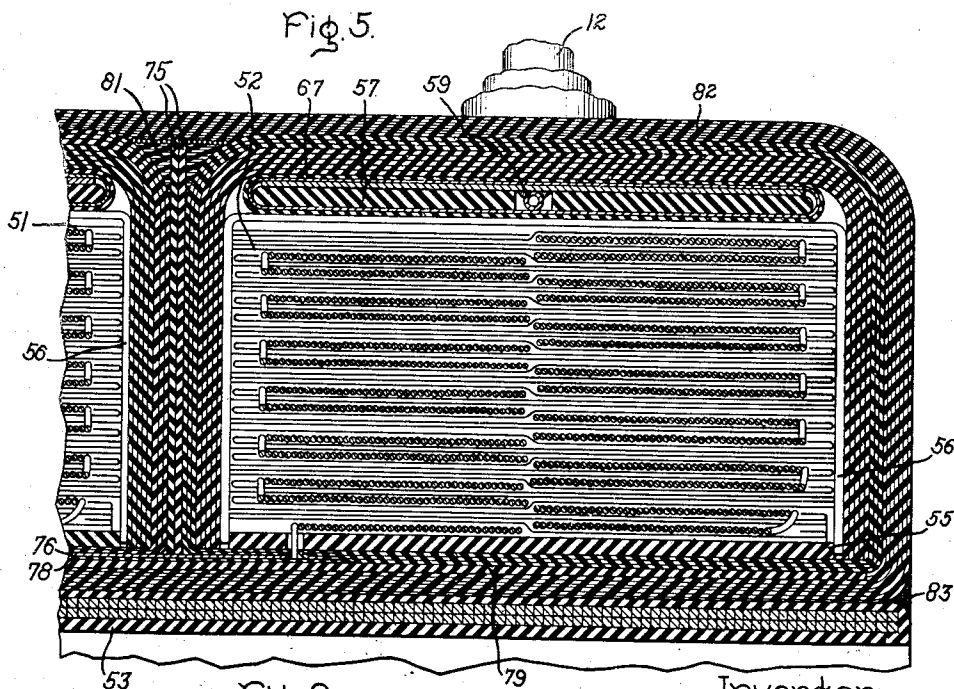
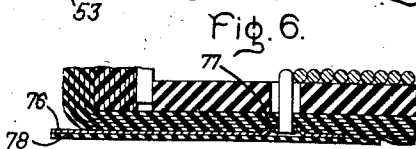
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ELECTRIC APPARATUS

Filed March 26, 1941

2 Sheets-Sheet 2



Inventor:  
Guglielmo Camilli,  
by *Harry E. Sunkam*  
His Attorney.

## UNITED STATES PATENT OFFICE

2,297,606

## ELECTRIC APPARATUS

Guglielmo Camilli, Pittsfield, Mass., assignor to  
General Electric Company, a corporation of New  
York

Application March 26, 1941, Serial No. 385,263

18 Claims. (Cl. 175—358)

The present invention relates to electric apparatus such as transformers and although not limited thereto it has application to high voltage potential transformers.

Instrument potential transformer for use with higher voltages are generally enclosed within a relatively large sealed tank, there being a space within the tank above the insulating liquid level of such size that the liquid may expand freely with variations in ambient temperature without danger of exposing any of the solid winding insulation and yet without creating too large a pressure differential within the tank.

Such transformers are inherently large and heavy so that they must be mounted upon sturdy foundations resting on the ground. This in turn necessitates that the high potential leads be brought down from the overhead transmission line for connection thereto, which entails considerable in the way of busbars and superstructure for supporting the high potential leads. A lightweight potential transformer, that is, one which may be readily mounted in the top of an existing conventional transmission line tower without the necessity for adding reinforcing members thereto is greatly to be desired so that only relatively short leads would be required extending from the transmission line conductors to the transformer terminals.

It is therefore a general object of the present invention to provide a new and improved high voltage transformer which is compact in design and relatively light in weight.

Another object of the invention is to provide a new and improved high voltage potential transformer which has a relatively small insulating liquid content.

It is a further object of the invention to provide a new and improved potential transformer so constructed and insulated with solid insulating material and a minimum of liquid insulation as to be suitable for use at very high voltages.

A further object of the invention is to provide an insulated electrical winding for electrical induction apparatus having a new and improved arrangement for withdrawing air or gaseous fluid therefrom during assembly of the apparatus.

And it is a further object of the invention to provide a transformer with a new and improved terminal bushing arrangement.

It is a still further object of the present invention to provide a transformer with a new and improved electrostatic shield arrangement.

For a consideration of what I believe to be novel and my invention, attention is directed to

the following description and the claims appended thereto taken in connection with the accompanying drawings.

In the drawings, Fig. 1 is a view, partly in section, of a transformer constructed in accordance with the present invention; Fig. 2 is a view in perspective of the transformer unit including the windings and core structure; Fig. 3 is a view in perspective of one high voltage coil embodied in the unit shown in Fig. 2 with portions removed for illustrating various details; Fig. 4 is a view further illustrating certain details of the coil shown in Fig. 3; Fig. 5 is a cross-sectional view through a portion of the winding assembly taken along the line 5—5 of Fig. 2; and Fig. 6 is an enlarged fragment of Fig. 5.

Referring first to Figs. 1 and 2, the transformer shown comprises a high voltage winding 10 having a pair of terminal leads 11 and 12 extending from diagonally opposite corners, a low voltage winding 13 nested concentrically within the winding 10 having terminal leads 14 and 15 and a magnetic core structure formed by a pair of ribbon wound units 16 and 17. The transformer unit is enclosed within a fabricated metal housing so shaped as to fit relatively closely thereabout. The housing comprises a lower section formed by vertical side wall portions 19, and a horizontal bottom wall portion 20 connected to the vertical walls 19 by intermediate wall portions 21 which slope at an angle determined by the general contour of the enclosed transformer units. The opposite ends of the lower housing section are closed by vertical end walls 22 which extend beyond the bottom wall 20 and are flanged at their lower edges 23 where- by the transformer may be secured upon a suitable support. The housing further includes a cover comprising an upper horizontal wall portion 24 and downwardly sloping wall portions 25 terminating in flanges 26 which may be welded to corresponding flanges on the upper edge of the lower housing section.

The magnetic core units 16 and 17 are clamped between angle members 27 and 28 by means of bolts 29, the lower ends of which bolts may be threaded into the crossbars 31 suitably secured as by welding to the opposite sloping side walls of the lower housing section for fastening the transformer unit in place. The low voltage winding leads 14 and 15 are brought through suitable insulating bushings provided in an end wall of the lower housing section to terminals 32 and 33.

The high voltage winding leads extend out-

warly from diagonally opposite points of the housing cover in order that the high voltage terminals will be spaced a sufficient distance apart. The high voltage terminal structures include a pair of porcelain bushing insulators 35 and 36 which are suitably secured at their lower ends to cooperating cylindrical extensions 37 and 38, respectively, from the cover of the transformer housing.

The insulators 35 and 36 are hollow and communicate through their lower ends with the interior of the transformer housing around the insulated leads 11 and 12. The upper portion of each insulator is enlarged so as to provide an expansion chamber 41 for the insulating liquid contained within the transformer and rising within the hollow insulators to a point above the solid insulation of the transformer unit. Thus it will be obvious that the insulating liquid level, indicated at 42, may rise and fall within the expansion chambers in accordance with ambient temperature conditions. The expansion chambers should be sufficiently large so that the compression of the inert gas which is preferably provided above the liquid surface will never be so great as to be likely to cause breakage of the porcelain insulators. The winding leads are connected by conductors or terminal leads 43 to the terminals 44 sealing the upper ends of the insulators. The conductors 43 include a short helical section 45 which prevents mechanical stresses being transmitted through the conductors. Surrounding the winding leads 11 and 12 extending into the insulators 35 and 36 are insulating collars 46 and tubes 47 which add to the dielectric strength of the insulation between the leads and the grounded casing. These parts are anchored in place by an insulating nut 48 secured to the connection 43.

In the transformer construction thus far described it will be observed that a very small amount of space is provided around the core and coil structure within the enclosing housing. The volumetric capacity of the transformer for insulating liquid is therefore reduced to a minimum so that the expansion and contraction of the body of insulating liquid will cause relatively slight variations in the liquid level in the expansion chambers of the insulator bushings.

In this transformer construction it will be apparent that liquid insulation is relied upon to a relatively small extent for providing the major insulation of the high voltage winding. For this latter purpose relatively thick solid insulation is provided as will be presently described, and special means are further provided for minimizing the possibility of voids and entrapped air pockets within the structure which might give rise to corona discharges within the winding and which might result in an ultimate breakdown of the insulation. For this purpose the winding leads 11 and 12 which terminate in the upper portions of the winding, the conductors 43 and the insulator terminals are all tubular and so sealed together as to provide passages whereby all traces of air may be withdrawn from the winding during the vacuum treatment of the transformer and as the insulating liquid is introduced into the housing a small opening 49 is provided in each terminal to permit the withdrawal of air from the interior of the bushings and for introducing a suitable inert gas thereto after the vacuum treatment has been completed.

The details of the winding structure are more clearly shown in the Figs. 3 to 5, inclusive, of the

drawings. Referring first to Fig. 5, the high voltage winding 10 comprises a pair of layer wound coils 51 and 52, each comprising a plurality of layers of conductor turns separated by intervening layers of insulation. The two coils are arranged coaxially in a side by side relation upon an insulating tube 79 and have their inner end turns connected together. The two coils are of a substantially similar construction so that only one will be described in detail. The coils are wound separately upon a tube 55 of insulating material in a manner well known in the art, the inner end turn being brought through a cooperating opening provided in the tube 55 for connection to the adjacent coil. U-shaped spacers 56 are then placed over the completed coils at the upper portion thereof so as to provide a suitable fluid passage or channel 56' between the opposite sides and top of the coils and the insulation wrapping. These spacers as are shown more clearly in Fig. 3 comprise relatively narrow strips of insulating material and are spaced apart so as to support the insulation wrapping away from the coils. As will be seen in Fig. 3, this passage connects with the outside edges at the top of each of the concentric windings. Thus, upon the introduction of a suitable insulating fluid, such as oil, to the coil in a conventional manner, that is at a lower portion, gaseous impurities such as air and moisture will be displaced by the oil and will travel around the small channels which are present at the edges of the concentric coils, which may be seen in Figs. 3 and 5, and will accumulate at the top in the chamber 56'. The gaseous impurities will then be drawn off through a suitable fluid passage such as that provided by the hollow terminal leads which passage has an opening beneath the insulation or communicates with the chamber 56' and is adapted to be connected with the space outside the insulation. An opening in the casing closable by a plug 85 may be provided, as will be seen in Fig. 1, through which the oil may be introduced. Wrapped around the outer circumference of each coil is an electrostatic shield which comprises a longitudinal strip 57 of insulating material having a width slightly less than the width of the coil and a length slightly less than the coil circumference. One end of the strip 57 is provided with a longitudinally extending slot 58, see Fig. 4, for cooperatively receiving a length of a small tube 59 which in turn is soldered to the under side of a small rectangular copper plate 61. At the inner end of the slot 58 the tube is bent upwardly and extends through a cooperating opening 62 provided through the plate 61 and is secured within a short sleeve 63 brazed to the opposite side of the plate 61 around opening 62. The plate 61 is fitted over the slotted end of the insulation strip 57 with the tube 59 extending through the slot 58 and terminating at the outer end thereof. The insulation strip 57, including the plate 61, is then wrapped with a metal foil 65 throughout its full length. The outer end turn of the coil is then soldered to the foil wrapping as indicated at 66, a small hole being first cut through the foil wrapping so that a good soldered connection is simultaneously made to both the foil and the copper plate 61 therebeneath. The high voltage terminal lead is adapted to be soldered into the sleeve 63 so that an electrical connection is made to the outer end of the coil through the plate 61. The electrostatic shield is then wrapped throughout its length with a layer or covering of suitable insulating material indicated at 67 and the

insulated shield is then fitted around the periphery of the coil. The ends of the shield are arranged at the uppermost portion of the coil providing a small gap or space 69 between the adjacent shield ends and which gap is also between the U-shaped spacers 56. The coil and electrostatic shield are then wrapped with a plurality of turns of insulating material indicated at 71 covering the outer surface and the opposite sides of the coil. The insulation layer 71 provided upon the coil is U-shaped in cross section and is formed by wrapping tangentially onto the coil a web of a relatively resilient insulating material, such as crepe paper, a small hole being cut in each turn for cooperatively fitting over the outwardly projecting sleeve 63. The web is stretched as it is wrapped onto the coil so that the opposite edges of the web will fit snugly against the opposite coil sides. After a layer of a considerable thickness has been applied onto the coil in the manner described, and the end of the web is suitably anchored, the winding lead is soldered into the sleeve 63 and an additional toroidally wrapped layer of insulation 73 is then provided on the coil and which layer is also extended around the winding lead. The last insulation layer 73 is then slit on the inside of the coil at the proper point for fishing out the inner end of the coil conductor. Thus, while the enclosing insulating covering which, as will be seen in Fig. 3, substantially encloses and may relatively closely fit the winding or be contiguous with outside surfaces of turns of the winding and therefore restricts passages or channels through which gaseous impurities such as air may be withdrawn or removed between the winding turns and inside the insulating covering, since the terminal lead passage has an opening beneath the insulating covering, the gaseous impurities may be withdrawn from these restricted passages or interstices. As will be seen in Fig. 1, the end of the terminal lead 43 which is adapted to communicate outside the insulated winding is closed by a plug 86 after the impurities have been withdrawn.

The two coils are then placed side by side with a number of rings 75 of insulating material arranged therebetween and the inner ends of the two coils are connected together, as is more clearly indicated in the enlarged fragmentary view of Fig. 6. The interconnection is made by means of a rectangular strip 76 of suitable metal such as copper and which has a pair of holes punched therethrough and spaced apart an amount equal to the distance between the conductor holes in the coil supporting cylinders. The strip 76 is fitted over the conductor ends which are then soldered thereto as indicated at 77. The corners of the rectangular connection strip are preferably rounded and are covered with a piece of cloth 78 which has been impregnated with a suitable semiconductive material, such as that commonly known in the trade as "Rescon." The strip 78, which is cemented in place, is somewhat larger than the metal strip 76 and extends beyond the edges of the latter so as to grade the potential at the edge of the metal strip 76 and thereby prevent the concentration of the dielectric stress at such point. An insulating tube 79 having a length substantially equal to the length of the insulated two coils is then slid therethrough.

The V corners 81 on the opposite sides of the insulation rings 75 are then packed with a suitable insulating material forming a substantially flat surface across the two coils. The two coils arranged in a side by side relation upon the cylin-

der 79 are then further toroidally wrapped with a relatively large number of turns of insulating material, such as crepe paper, forming a layer 82, to a total thickness as required for the operating voltage of the coils. The last mentioned insulating procedure also includes providing additional insulation around the leads 11 and 12 over a sufficient length as determined by the dimensions of the insulator bushings and the cylindrical cover extensions 37 and 38.

The low voltage winding assembly is then inserted into the high voltage winding and the corners 83 therebetween are packed with suitable insulating material so as to provide a substantially smooth surface across the ends of the unit. It is to be understood that it is quite important that such irregular pockets and crevices be filled with solid insulation wherever they occur. If such spaces are left to be filled with insulating liquid, because of the lower permittivity of the latter, corona will generally be formed at these points at relatively low voltages.

The magnetic core units 16 and 17 are then wound onto the winding assembly and the whole is thoroughly dried and baked so as to remove substantially all traces of moisture therefrom. It is then mounted within the metal housing and the bushing insulators are arranged in place. A suitable exhausting pump is then connected to the outer ends of the terminals and air is withdrawn from the interior of the housing as insulating liquid is slowly admitted thereto. It will be obvious that inasmuch as the air is withdrawn from the upper portion of the winding coils through the tubes 59 arranged in the ends of the electrostatic shields, no pockets of entrapped air will be left within the windings.

Having described my invention in what I consider to represent the preferred embodiment thereof, I desire to have it understood that the specific structural details shown are merely illustrative and that the invention may be carried out in other ways.

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

1. An electric apparatus comprising a winding having a plurality of turns, a layer of insulation relatively closely surrounding and substantially enclosing said winding and thereby restricting passages through which gaseous impurities may be removed from interstices between winding turns, a high voltage terminal for said winding, a connection between said terminal and said winding, said connection being hollow and adapted to communicate outside said insulating layer and communicating with the interstices between winding turns beneath said insulation layer whereby gas may be withdrawn therefrom.

2. An electric apparatus comprising a winding having a plurality of turns, a layer of insulation relatively closely surrounding and substantially enclosing said winding and thereby restricting passages through which gaseous impurities may be removed from interstices between winding turns, a terminal for said winding, a connection between said terminal and said winding, said connection comprising a tubular conductor adapted to communicate outside said insulating covering and having an opening in the uppermost portion of said winding beneath said insulation layer and communicating with interstices between winding turns whereby gaseous impurities may be withdrawn from said winding.

3. In electrical induction apparatus, a winding immersed in insulating liquid, said winding com-

prising a plurality of conductor layers, a layer of insulating material relatively closely surrounding and substantially enclosing said winding and thereby restricting passages through which gaseous impurities may be removed from interstices between winding turns, a terminal for said winding, a connection between said terminal and said winding comprising a tubular conductor communicating between an opening in said terminal and the interstices between winding turns beneath said insulating layer at the upper surface of said conductor layers.

4. A transformer comprising a winding, a layer of insulation relatively closely surrounding and substantially enclosing said winding, spacing means between said winding and said insulation layer along one side and across the top of said winding, a high voltage terminal for said winding, a connection between said terminal and said winding, said connection comprising a tubular conductor communicating with the space between said winding and said insulation layer adjacent the upper portion of said winding, a fluid-tight housing for said winding, means for admitting insulating liquid into said housing while air is withdrawn therefrom through said tubular conductor.

5. A transformer comprising a winding, a conductive electrostatic shield substantially surrounding said winding, a layer of insulation surrounding said shield and said winding, a terminal for said winding, a connection between said terminal and said winding, said connection comprising a tubular conductor extending through said insulation layer conductively connected to said shield and said winding, the inner end of said tubular conductor being arranged within said shield, adjacent ends of said shield defining a space in the upper portion of said winding, the end of said tubular conductor communicating with the space between the ends of said shield.

6. A transformer comprising a layer wound coil having layers of insulation between conductor layers, an electrostatic shield substantially surrounding said winding and having a pair of spaced apart ends at the upper portion of said winding, an insulation layer surrounding said winding and said shield, spacing means between the sides of said winding and said insulation layer, the spaces at the sides of said winding communicating with the space between the ends of said shield, the outermost turn of said winding being connected to said shield, a terminal for said winding, a connection between said terminal and said shield comprising a tubular conductor the inner end of said tubular conductor communicating with said space at the upper portion of said winding.

7. A transformer comprising a pair of layer wound coils, said coils being arranged coaxially in a side by side relation, each of said coils being relatively closely surrounded and substantially enclosed by a corresponding insulation layer and thereby restricting passages through which gaseous impurities may be removed from interstices between the layers, the inner end turns of said coils being connected together, a terminal for each of said coils, connections between said terminals and the outer end turn of the corresponding coil, said connections each comprising a hollow tubular conductor communicating with the space in the uppermost portion of each of said coils beneath said insulation layers.

8. A transformer having a winding comprising

a pair of layer wound coils, said coils being arranged coaxially side by side and having corresponding inner end turns connected together, a housing for said transformer relatively closely surrounding said winding, a terminal structure for each of said coils mounted on said housing adjacent the corresponding coil and adjacent opposite sides of said winding.

9. A transformer having a magnetic core structure and a winding arranged thereon, a housing surrounding relatively closely said core structure and said winding, a hollow bushing insulator mounted on the cover of said housing and having a conductive terminal, the interior of said insulator communicating with the interior of said housing, said insulator defining an enlarged expansion chamber in the upper portion thereof for insulating liquid contained within said housing and insulator, a connection between said terminal and said winding, said connection having a helically coiled portion in said chamber.

10. In an electric apparatus, a winding having a plurality of layers, a layer of insulation relatively closely surrounding and substantially enclosing said winding, a high voltage terminal for said winding, means including said layer of insulation providing a fluid passage at edges of layers of said winding, a connection between said terminal and said winding, said connection being hollow and communicating with said fluid passage beneath said insulation layer whereby gas may be removed therefrom.

11. In an electric apparatus, a winding having a plurality of turns, a conducting terminal lead connected to said winding, an insulating covering substantially enclosing said winding and contiguous with outer surfaces of turns of said winding thereby restricting passages through which gaseous impurities may be withdrawn from interstices between said winding turns, and a casing surrounding said winding and a portion of said terminal, said terminal having a fluid passage adapted to communicate outside said casing and an opening beneath said insulating covering and communicating with the interstices between said winding turns so that gaseous impurities may be withdrawn from the interstices through said terminal lead passage during a treating operation of said winding.

12. In an electric apparatus, a winding having a plurality of turns, an insulating covering substantially enclosing and closely fitting said winding thereby restricting passages through which gaseous impurities may be withdrawn from interstices between said turns, and a tube having a fluid passage adapted to communicate outside said insulating covering and an opening beneath said insulating covering and communicating with the interstices between said winding turns so that gaseous impurities may be withdrawn from the interstices between said winding turns through said fluid passage of said tube during a treating operation of the apparatus.

13. An electric apparatus including a winding, insulation surrounding said winding, a casing surrounding said winding, a bushing on said casing and having an opening communicating with the space inside said casing and around said winding and said insulation, and a hollow terminal lead within said bushing electrically connected to said winding and having an opening communicating with the winding inside said insulation.

14. An electric apparatus including a winding, insulation surrounding said winding, a casing

surrounded said winding, a bushing on said casing and having an opening communicating with the space inside said casing and around said winding and said insulation, and a hollow terminal lead within said bushing electrically connected to said winding and having an opening communicating with the winding inside said insulation, said hollow terminal lead also communicating with the space inside said hollow bushing and around said terminal lead.

15. An electric apparatus including a winding, insulation surrounding said winding, a casing surrounding said winding, a bushing on said casing and having an opening communicating with the space inside said casing and around said winding insulation, and a tube within said bushing, said tube adapted to communicate outside said bushing and having an opening communicating with the winding inside said insulation so that gaseous impurities may be withdrawn from restricted passages inside said insulation through said opening and tube.

16. In an electric apparatus, a winding having a plurality of turns, a conducting terminal connected to said winding, a porous insulating covering substantially enclosing and relatively closely fitting said winding, a casing surrounding and relatively closely fitting around said winding, said terminal lead having a fluid passage adapted to communicate outside said insulating covering and having an opening beneath said insulating covering communicating with interstices between said winding turns so that gaseous impurities may be withdrawn from the interstices, and an insulating fluid in the winding space within said

casing permeating said insulating covering and filling a portion of said fluid passage of said terminal lead.

17. An electric apparatus including a winding having a plurality of conductor layers, insulation between said layers, a layer of insulation relatively closely surrounding and substantially enclosing said conductor layers, a housing surrounding said winding, a hollow bushing insulator mounted on said housing and having a conductive terminal, the interior of said insulator communicating with the interior of said housing, an insulating fluid within said housing permeating said layer of insulation and filling a lower portion of said bushing, an upper portion of said bushing defining an expansion chamber, means for admitting said fluid to said housing, and a connection between said terminal and said winding, said connection being hollow and communicating beneath said enclosing insulating layer.

18. An electric apparatus including a winding having a plurality of turns, a layer of insulation relatively closely surrounding and substantially enclosing said winding, means for introducing an insulating fluid to said winding near the bottom thereof to permeate said layer of insulation, and a tube having a fluid passage adapted to communicate outside said insulating covering and communicating inside said insulating layer near the top of said winding so that impurities displaced by said fluid may be withdrawn from inside said layer of insulation through said tube.

GUGLIELMO CAMILLI.