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March 18, 1958

M. L. MANNING

2,827,616

HIGH TEMPERATURE TRANSFORMER CONSTRUCTION OR THE LIKE

Filed Aug. 6, 1952

2 Sheets-Sheet 1

Fig. 1.

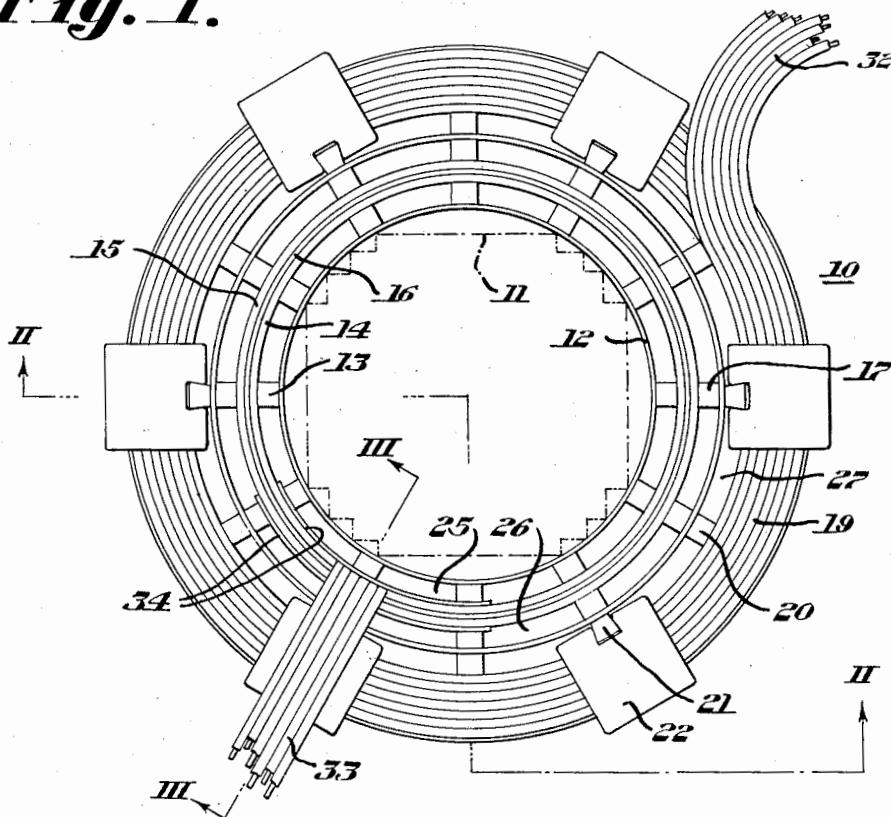
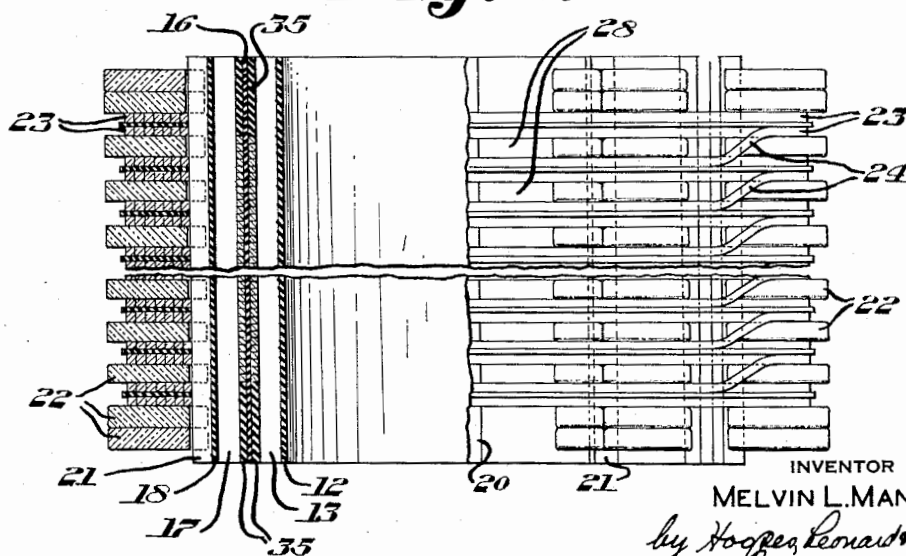


Fig. 2.



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March 18, 1958

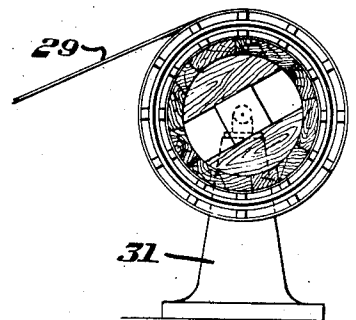
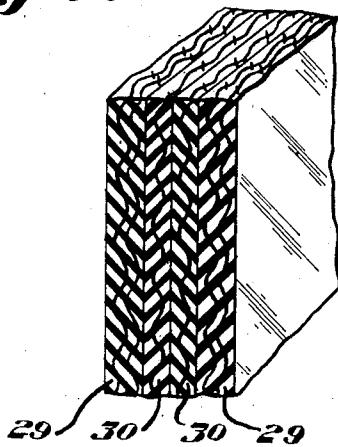
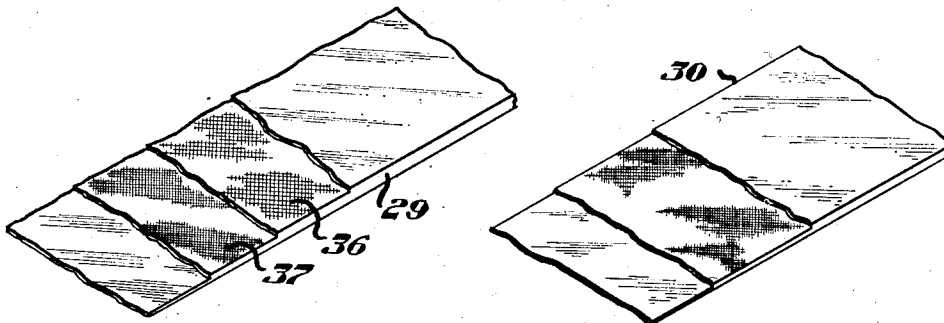
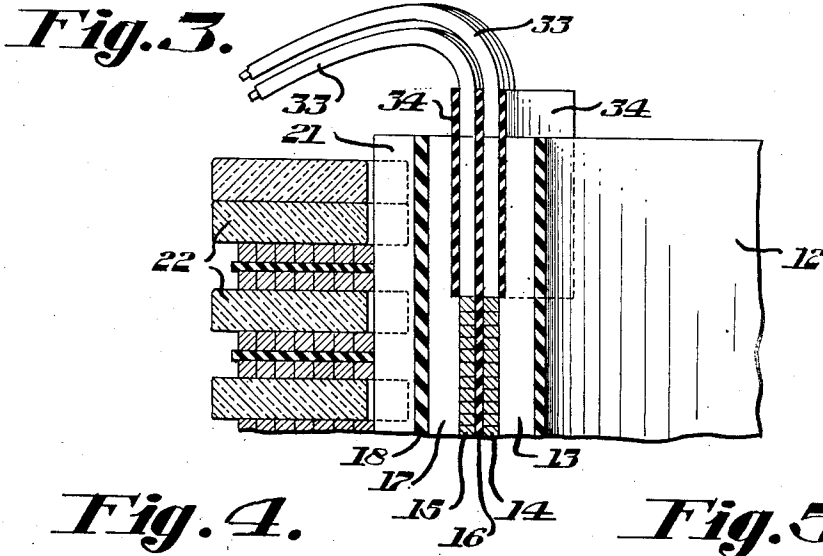
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HIGH TEMPERATURE TRANSFORMER CONSTRUCTION OR THE LIKE

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2 Sheets-Sheet 2



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2,827,616

HIGH TEMPERATURE TRANSFORMER CONSTRUCTION OR THE LIKE

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Application August 6, 1952, Serial No. 302,887

13 Claims. (Cl. 336—196)

This invention relates to a new high temperature transformer construction or the like. More particularly, it pertains to a new kind of transformer or the like in which silicone and fiber insulating materials are combined.

High temperature transformers and other high temperature electrical induction constructions have been an objective of various manufacturers for some time. The work in that direction received added impetus upon the widespread introduction of silicone materials a few years ago. Despite the recognition of the electrical qualities of such materials, a number of drawbacks attended use of them. One manufacturer despite the availability of such silicone materials provided heat-resistant glass cylinders for insulating barriers.

I have discovered a new construction which enables the remarkable properties of silicone materials to be fully employed for insulation and support purposes to provide a transformer or the like with a class-H rating. At the same time, I am enabled to shield the leads and windings by means of my new construction in a manner which preserves the advantages thereof without risk of creepage or breakdown in that area. Other advantages of my new construction are that it provides protection against local dielectric and thermal weakness points and permits efficient construction practices to be employed.

Other objects and advantages of this invention will be apparent from the following description and from the drawings, which are illustrative only, in which

Figure 1 is a plan view, partly schematic, of low and high voltage windings, barriers and spacers of a high temperature dry transformer embodying my invention;

Figure 2 is a view in elevation of the structure shown in Figure 1 taken along line II—II of Figure 1;

Figure 3 is a somewhat detailed view of the portion of the structure shown in Figure 1 adjacent the low voltage winding leads and shielding, taken along the line III—III of Figure 1;

Figure 4 is an illustrative dissected view of a formable silicone resin laminate employed in my new construction;

Figure 5 is an illustrative dissected view of a flexible silicone rubber and fiber ply material employed in my new construction;

Figure 6 is a section through a core to low voltage winding barrier in my new construction showing the silicone materials of Figures 4 and 5 in an interleaved combination; and

Figure 7 is a diagrammatic showing of one end of a transformer embodying my invention in the course of being constructed.

Referring to the drawings, a power transformer 10 is shown in Figures 1 and 2 in sufficient detail to illustrate the new construction features in one embodiment of my invention. In that embodiment, a cruciform laminated core leg 11 of a conventional magnetic core may be illustrated as shown in Figure 1 by dot-and-dash lines. A core to low voltage winding (CL) barrier envelope 12 surrounds core leg 11 in close proximity thereto. Axial spacers 13 may be positioned around the outside of CL

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barrier 12 in spaced arrangement where they are held in the course of the winding of the concentric layers 14 and 15 of a helically wound low voltage winding. Spacers 13 may be held against barrier 12 by a suitable silicone adhesive or other means. The conductors employed in winding the low voltage winding layers 14 and 15 may be wire which is served with a glass silicone resin bonded tape insulation prior to winding. In other cases, such conductors may be served with other materials such as flexible asbestos or glass cloth silicone tape or "Teflon" tape. Insulation in the form of a cylindrical envelope 16 may be interposed between the layers 14 and 15 by using, for example, silicone rubber ply material similar to that employed in the construction of CL barrier 12.

A further series of axial spacers 17 may be held against and spaced around the exterior of the low voltage winding coil comprising layers 14 and 15. A further insulating (HL) barrier envelope 18 between the low voltage coil 14—15 and a high voltage coil 19 may be provided under my new construction entirely of silicone and fiber matrix materials. HL barrier 18 may comprise a combination of more of the interleaved plies than the number used for the CL barrier as shown in Figure 6. Barrier 18 insulates the low voltage windings from the high voltage windings and must withstand the relatively high voltage potentials and thermal increases to which it is subjected. A further series of axial spacers 20 of solid or molded U shapes may be fastened at uniform intervals around and to the exterior of HL barrier 18. Alternate spacers 21 in the series of spacers 20 may be of keytone shape, if desired, to permit keying engagement with and movement during assembly for lateral spacers 22.

The high voltage coil 19 may comprise a plurality of double layer horizontal pancake windings 23 in vertically stacked arrangement as shown in Figure 2, respective ones of said such windings being interconnected electrically by crossover conductors 24. The radial spacers 22 may be made of a mechanically and electrically strong material like porcelain. Axial spacers 13, 17 and 20 may be made of class-H insulating material in the form of solid or channel-shaped spacers. As an example, I have discovered that glass cloth or asbestos cloth bonded with silicone resin materials may be molded or otherwise shaped and cured to provide axial spacers of markedly superior mechanical and dielectric strengths. The annular pressure plates and tie rods which respectively bear endwise on the respective windings and lateral spacers 22 have not been illustrated as such features will be well understood by those skilled in the art. The vertical ducts 25 between the axial spacers 13, the vertical ducts 26 between the axial spacers 17, the vertical ducts 27 between the axial spacers 21 and the lateral ducts 28 between the lateral spacers 22 afford access to the turns of the respective windings for whatever cooling or ambient fluid may be employed. In the case of a sealed dry-type transformer embodiment, a gas like nitrogen may be used to fill the gas space within a transformer tank in which my new construction is placed.

In construction the embodiment shown in Figures 1 and 2, one mode of making the new barrier envelope is illustrated in connection with making a barrier 18 and other barrier 12 may be similarly made. In the transformer or the like being constructed, any entire or other partial barriers, whether cylindrical or arcuate, may be constructed in accordance with my invention. In that invention, one or more sheets 29 of a formable silicone resin and fiber laminate is combined in interleaved manner with one or more plies 30 of flexible silicone rubber and fiber material. Generally, in preparing a cylindrical envelope barrier in accordance with this invention, each kind of material is formed into the desired cylindrical shape beginning with the innermost layer. Thus, a cylinder of the laminate may be provided and the ends over-

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lapped and fastened by a silicone adhesive, for example, or by class-H tapes of sufficient strength, enough turns being made in the laminate layer to provide a due share of the total insulation of the new combination. Then one or more layers of the silicone rubber and fiber material may be formed in cylindrical shape around the laminate and the outermost end of said material fastened again by silicone adhesive or other means. In some cases, the laminate material may have a silicone rubber layer affixed to one or both surfaces of the laminate before the laminate is formed. Around the silicone rubber and fiber material, another one or more layers of laminate material may be wound against the exterior of the silicone rubber and fiber material layer or layers to complete the interleaving. As shown in Figure 6, barrier 12, for example, may be made in the form of a right cylinder, the innermost layer of which as shown is a layer of formable laminate surrounded by two layers of silicone rubber and fiber in turn surrounded by a single layer of laminate again, the entire construction comprising a single barrier envelope with markedly superior features, both dielectrically and mechanically, to any insulation heretofore provided.

The construction of a new barrier envelope may be performed in a winding lathe such as those used in the transformer industry. For example, as illustrated in Figure 7, a barrier such as HL barrier 18 is shown being formed in place. The CL barrier has already been formed and is molded in a lathe 31 which rotates in the direction of the arrow. If desired, a steel cylinder may be used as the innermost mold to initiate the construction of barrier 12 thereagainst in which event a mold release compound, for example, may be used between the exterior of the mold cylinder and the interior cylindrical surface of the CL barrier 12. In the partially completed construction shown in Figure 7, the axial series of spacers 18 has been positioned, the low voltage winding 14-15 has been wound on the lathe around the spacers 13, the spacers 17 have been positioned and the lathe is in the midst of winding the HL barrier 18 as aforesaid with a strip 29 of laminate. Enough layers of silicone laminate and silicone rubber material will be utilized in the new interleaved relation to provide the necessary mechanical and dielectric strength required for the high-low voltage barrier envelope service in the particular transformer or the like under construction. When such winding of barrier 18 is completed, that barrier, as is the case of barrier 12, will have sheets 29 and 30 interleaved throughout. Preferably, the sheets 29 and 30 are of a width equal to the entire height of the transformer windings plus the additional height equal to the keep-back insulation length desired at the respective axial ends of the transformer or the like.

The new construction of this invention also effects a marked improvement in taking care of lead outlets particularly in the case of the more interior windings such as the low voltage coil 14-15 shown in the illustrated embodiment. Leads 32 from the high voltage coil 19 do not generally present any particular problem in the case of an embodiment such as that shown because of their presence in the vicinity of the exterior of the transformer where they can, for example, be readily conducted upwardly through an insulating tube, which, again, may be made of tubular silicone material now available on the market.

On the other hand, conductor leads 33 are generally connected not only to the ends of the low voltage coil 14-15 but also to intermediate points therein and all of the leads or taps have to have an outlet from the interior of the embodiment of the new transformer which is shown. In my invention, cylindrical insulation plates 34 which are arcuate and may be preformed of interleaved layers of laminate like laminate 29 alternating with interleaved layers of silicone rubber material like

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ply 30 are provided and inserted in place as shown in Figures 1 and 3 generally in the course of the construction winding as on lathe 31. The surface of the insulation exposed to the lead or leads is preferably faced with a silicone rubber coated glass cloth or asbestos cloth.

In such construction, as an example, the innermost plate 34 may be pinched between and held between the top turns of layer 14 and the adjacent axial spacers 13 on the other side of that plate 34. On the other hand, if keep-back insulation of a class-H category is interposed between the plates 34 above the topmost turn of the layers 14 and 15, and, on each side of leads 33 in a circumferential direction, as shown in Figure 3, then the plates 34 may respectively be held between such keep-back insulation 35 and the axial spacers 13 and 20 respectively. The height of the plates 34 above the barriers 12 and 18 guards against creepage and any possibility of short-circuiting at the outlet shown of the taps 33 relative to parts of the transformer at different voltage potentials.

Laminate sheets such as sheets 29 may now be obtained as a commercial article having a fiber cloth matrix of an inorganic material like heat-cleaned glass or asbestos. Such fibrous matrix in the case of glass, for example, may be in part a staple cloth 36 woven of short lengths of glass filaments in the manner of a staple vegetable fiber cloth. Laminate 29 also preferably employs a fiber matrix cloth 37 woven of continuous glass filaments placed in juxtaposition to the cloth 36. These cloths 36 and 37 are impregnated with a silicone resin which enters the interstices of the cloth and wholly covers them to form, when solidified, the laminate sheets 29. In place of such fiber matrix, it may also be possible to use such inorganic fibers in the form of a felted cloth or matte highly resistant to electrical, mechanical and thermal deterioration. The silicone resins may be of a kind such as those sold by Dow Corning Corporation under the trade identification "DC 2104." A silicone material laminate of suitable character for employment in my invention is one such as that made by Mica Insulator Company of Schenectady, New York, having the trade designation "E-724 Lamacoid." In preparing laminate 29, usually from 40 to 60 percent of the weight thereof will be the partially or wholly cured and solidified silicone resin. In applying the laminate 29, it is preferable to place the staple cloth 36 on the inside of the bend and the continuous fiber cloth 37 on the outside, generally with the warp of both cloths parallel to the longitudinal axis of the insulation envelope or cylinder being constructed.

Suitable silicone rubber plies such as the sheet 30 are also now commercially available on the market for employment in my invention. Such a silicone rubber material may comprise a cloth of inorganic fiber like glass or asbestos, thoroughly heat-cleaned to remove organic binders, which cloth forms a matrix for a silicone rubber coating. One suitable silicone elastomer for such coating purpose is "Silastic," a trade name of Dow Corning Corporation, which corporation also makes a suitable silicone rubber and fiber matrix material suitable for the sheets 30. The fiber glass which may be utilized in the construction of the new insulation components of this invention should have characteristics suitable for satisfactory electrical, mechanical and thermal service in a class-H transformer. Certain of the glass products termed "Fiberglas" by Owens Corning Fiberglas Corporation are suitable in making up the matrices for silicone sheet materials like sheets 29 and 30.

In my employment of such new insulation in a transformer or the like, I have also found it useful to have the dielectric constants of the interleaved sheet materials like sheets 29 and 30 of about the same dielectric constant, which may be in the neighborhood of 3.5. Thereby, the gradient through the materials in series because of their interleaved relation appears to be relatively uniform and

the voltage strength throughout the new insulation structure will also be generally uniform and foci of weakness for breakdown in the course of use are avoided. The use of various filler materials such as titanium dioxide or zinc oxide may be employed in the manufacture of the silicone rubber material, as will be well understood by those in the art to whom this invention is disclosed, to achieve relative equality of the dielectric constants of the component laminate and silicone rubber materials in the composite insulation. Other ways may be employed to harmonize the respective constants of the two sheet materials.

In constructing the new transformer the laminate may be formed cold for bent diameters exceeding about 10 inches whereas formerly it was believed that such kind of material had to be heat formed. I find, however, that not only may such material be cold formed but that such cold forming for laminates not in excess of about $\frac{1}{32}$ of an inch in thickness does not produce any tendency to craze it, particularly when used in cooperation with a silicone rubber material like the sheets 30 having a thickness between about $\frac{1}{64}$ of an inch and $\frac{1}{32}$ of an inch. In some cases the laminate, particularly for smaller diameter uses or thicker sheets, may be heated to about 165° C. for a relatively few minutes generally not in excess of four.

It appears that the new composite insulation forms a unitary mass which functions ideally as the supporting framework for the windings of the new transformer and provides dielectric characteristics and strength between the various parts of the transformer at different potentials to enable a new transformer to function in the class-H category without the disabilities of prior transformers in such category. The sheet materials 29 and 30 so employed may in the case of the laminate be partly or fully cured whereas in the case of the silicone rubber and fiber matrix material it will generally be in a partly cured state. Curing of the insulation after completion of the winding assemblies may be performed at a temperature at about 250° C. Prior to such curing, the winding assembly may be dipped into a silicone type of varnish, as one example, to complete the mechanical binding of the new transformer windings and assembly. One advantage of such a varnish is that its high gloss reduces any opportunity for the settlement of dust or other contaminant which might constitute a leakage path and another is its high craze resistance. Thereafter, if not earlier, any mold cylinder which has been employed will be removed before the completion and performance testing of the entire transformer or the like.

A study of the advantages of my new composite insulation and cooperation in a transformer or the like leads to the belief that the interleaved substances complement one another in the course of use to a marked and unusual extent. For example, the silicone rubber and fiber matrix material appears to at least hinder the aging of the silicone resin and fiber matrix laminate and also to cooperate in dissipating any tendency to craze or crack which the laminate might otherwise have. Further, the heat conductive properties of the silicone rubber material appear to be superior to those of a silicone laminate such as that described with the consequence that the thermal lag of the one material like sheet 29 is materially aided if not overcome by the thermal conductivity of sheet material like sheets 30. Thereby the new transformers or the like can be consistently worked and operated at higher levels and/or for longer times as in the case of varying load cycles or load demands on transformers, without detriment.

The hot spot temperature standard of 180° C. set some years ago for class-H insulation can be materially exceeded by means of the present invention without any observable deterioration. In constructing the new transformer or the like, it will be understood that other insulating materials that may be used for other parts of the trans-

former than those described herein will be of suitable electrical and mechanical characteristics for the intended purpose. The invention is applicable not only to dry but also to wet transformers or the like and to ventilated and sealed transformers and the like.

Various changes may be made in the practice of the present invention without departing from the spirit thereof or the scope of the appended claims.

I claim:

1. In an electrical transformer, in combination, an at least partially cured silicone resin impregnated insulating sheet having a heat-cleaned inorganic fiber base material and an at least partially cured silicone rubber insulating sheet having a heat-cleaned inorganic fiber base material, said sheets being contiguous and positioned between and insulating portions of said transformer having a potential difference therebetween, said fibers being selected from a group consisting of glass and asbestos.

2. In a transformer, in combination, at least one formable silicone resin impregnated sheet having a heat-cleaned, continuous filament, inorganic fiber cloth, and at least one silicone rubber sheet having a heat-cleaned inorganic fiber cloth, said fibers being of a material selected from a group consisting of glass and asbestos, said sheets being contiguous and disposed between and insulating portions of said transformer having a potential difference therebetween.

3. In a transformer, in combination, a relatively thin, bendable, at least partially cured silicone resin impregnated sheet having heat-cleaned inorganic continuous filament and staple fiber cloths in superposed relation, and a relatively thin, at least partially cured silicone rubber sheet, said sheets being contiguous and positioned between and insulating portions of said transformer having a potential difference therebetween.

4. In a transformer, in combination, an insulation barrier comprising silicone resin impregnated sheets interleaved with silicone rubber sheets, said barrier being positioned between and insulating portions of said transformer having a potential difference therebetween, said sheets having approximately the same dielectric constant.

5. In a transformer, in combination, a bendable silicone resin impregnated sheet having an inorganic heat resistant and electrically insulating heat-cleaned fibrous cloth, and a flexible, at least partially cured silicone rubber coated sheet having an inorganic heat resistant and electrically insulating heat-cleaned fibrous cloth, said sheets being contiguous and positioned between and insulating portions of said transformer having a potential difference therebetween, said sheets further having approximately the same dielectric constant.

6. In an electrical transformer, the combination with a closed magnetic core having a winding leg and an electrical coil surrounding said winding leg of a tubular insulating barrier disposed between and insulating said leg and said coil comprising interleaved at least partially cured silicone resin impregnated sheets having a heat-cleaned, inorganic fiber, base material and at least partially cured silicone rubber sheets having a heat-cleaned, inorganic fiber, base material, said fibers being selected from a group consisting of glass and asbestos, said leg, said barrier, and said coil being bound together by a silicone varnish.

7. In an electrical transformer, the combination with concentric high and low voltage windings of a tubular insulating barrier interposed between and insulating said windings comprising interleaved silicone resin impregnated sheets having a heat-cleaned, continuous filament, inorganic fiber cloth and silicone rubber sheets having a heat-cleaned inorganic fiber cloth, said fibers being of a material selected from a group consisting of glass and asbestos, said barrier and windings being bound together by a silicone varnish.

8. In an electrical transformer, the combination with

concentric windings of a tubular insulating barrier interposed between and insulating said windings comprising formable silicone resin impregnated sheets interleaved with silicone rubber sheets, each of said sheets having a heat-cleaned inorganic fiber base material, said sheets further having approximately the same dielectric constant.

9. In an electrical transformer, an insulation barrier comprising at least one formable silicone resin impregnated sheet having a glass fiber base material and at least one silicone rubber sheet having a glass fiber base material, said sheets having approximately the same dielectric constant and being disposed between portions of said transformer having a potential difference therebetween.

10. In an electrical transformer, the combination of a cylindrical winding and an arcuate insulating barrier, said barrier comprising silicone resin impregnated sheets interleaved with silicone rubber sheets, each of said silicone resin sheets having at least one heat-cleaned continuous filament cloth and at least one heat-cleaned staple fiber cloth, said continuous filament cloth being disposed radially outward from said staple fiber cloth and having its warp parallel to the axis of said cylindrical winding, each of said silicone rubber sheets having at least one heat-cleaned cloth, said cloths being of fibers selected from a group consisting of glass and asbestos, said barrier being adjacent said cylindrical winding and insulating said winding from portions of said transformer at potentials differing from that of said winding.

11. In an electrical transformer, the combination with concentric windings of a tubular insulating barrier interposed between said windings, said barrier comprising silicone resin impregnated sheets interleaved with silicone rubber sheets, each of said resin impregnated sheets having at least one continuous filament cloth and at least one

staple fiber cloth, said continuous filament cloth being disposed radially outward from said staple fiber cloth and having the warp thereof parallel to the axis of said tubular barrier, each of said silicone rubber sheets having at least one inorganic fiber cloth, said cloths being of a material selected from a group consisting of glass fiber and asbestos fiber.

12. In stationary induction apparatus, in combination, at least one formable silicone resin impregnated sheet having a heat-cleaned inorganic filler and at least one silicone rubber sheet having a heat-cleaned inorganic filler, said sheets being contiguous and disposed between and insulating portions of said stationary induction apparatus having a potential difference therebetween.

13. In an electrical transformer, the combination of a cylindrical winding and an arcuate insulating barrier, said barrier comprising silicone resin impregnated sheets interleaved with silicone rubber sheets, each of said sheets having a heat-cleaned inorganic filler, said barrier being adjacent said cylindrical winding and insulating said winding from portions of said transformer at potentials differing from that of said winding.

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