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PROCESS OF IMPREGNATING ELECTRICAL INDUCTION APPARATUS

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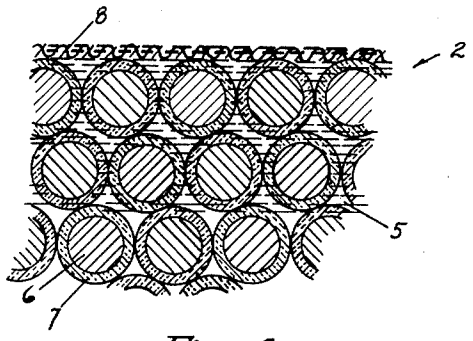


Fig. 1.

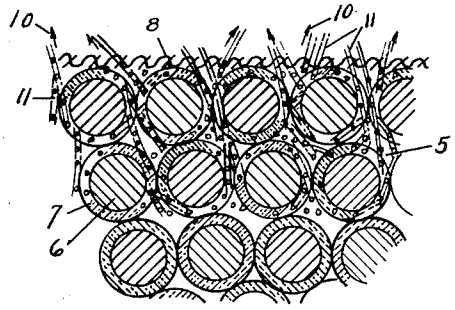


Fig. 2.

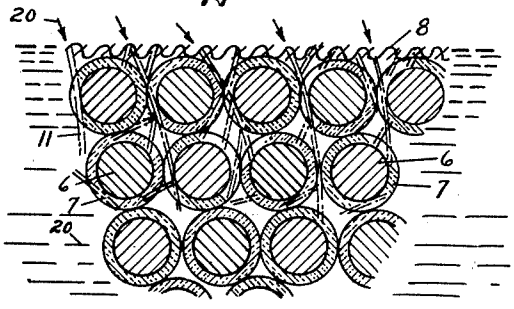


Fig. 3.

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PROCESS OF IMPREGNATING ELECTRICAL INDUCTION APPARATUS

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Application April 27, 1951, Serial No. 223,187

7 Claims. (Cl. 117—72)

This invention relates to electrical induction apparatus, and particularly pertains to a new and improved method of impregnation of said apparatus.

Reference is made to copending application, Serial No. 223,263, filed on April 27, 1951, by John O. Fenwick, and assigned to the same assignee as the present invention. The present invention is based primarily on the impregnation method disclosed in the above mentioned application, and is an improvement of that method. The above mentioned application disclosed a novel method of impregnating transformer coils, or core and coil assemblies to provide a unit that is both oil impregnated and, in addition, includes a superficial layer of varnish to obtain maximum short-circuit strength.

I have found that by using heat-reactive varnishes, which require relatively low baking or curing temperatures, the baking stage may be combined in one operation to simultaneously dry the insulation, and cure the varnish. In addition, I have found that by introducing a dry cooling stage subsequent to the baking operation, a transformer of superior electrical characteristics may be obtained.

It is well-known that various heat-reactive varnishes, when cured at relatively low temperatures, form inherent void spaces or cavities upon baking or curing. That is, when the volatiles are driven from the relatively thin varnish layer, the cavities remain. This invention takes advantage of those cavities that form passages extending through the entire layer, by utilizing these passages to permit moisture included in the insulation of the coil to be driven from the coil through the passages simultaneous with baking or heat curing operations. When the moisture has been driven from the unit, the passages are again utilized for oil impregnation purposes.

It is an object of this invention to provide a novel transformer impregnating process which includes a single baking or heat-curing stage which is used to simultaneously cure a superficial varnish layer, and provide a means for drying insulation.

Another object of this invention is to provide a transformer impregnating process that includes an air-conditioned, dry, cooling stage subsequent to the baking or curing operation and prior to an oil impregnation, which cooling stage acts to eliminate electromagnetic strain which may affect magnetic core steel, thereby to decrease core loss, in addition to increasing oil-proofness of the varnish.

A further object of this invention is to provide a method for impregnating transformer coils which includes an oil impregnation under evacuated conditions, thereby to provide maximum resistance to corona effects, and minimum power factor commensurate with insulation life.

Still another object of this invention is to provide as a new article of manufacture, an electrical induction assembly that has an impregnated superficial layer of heat-reactive varnish in addition to being impregnated with a dielectric oil and is further characterized by having any relating magnetic steel portions substantially strain-free for minimizing core loss.

For a clear understanding of the nature and objects of the invention, reference should now be had to the following detailed description and drawing in which:

Fig. 1 is an enlarged fragmentary cross-sectional view of a portion of the outer windings and insulation of a coil impregnated under the novel process illustrating the

semi-fluid condition of the superficial layer of varnish upon entry of the assembly into the curing oven.

Fig. 2 is a view similar to Fig. 1 illustrating the formation of cavities in the superficial layer of varnish curing baking or curing, and further showing the evolution of water vapor from the internal winding layers.

Fig. 3 is another view similar to Fig. 1 illustrating the dual use of the cavities formed in the superficial varnish layer—that is, the admission of a dielectric oil impregnant to the coil interior after cooling of the unit.

For illustrative purposes, a coil and core assembly may be manufactured under the usual practices (not shown). A preferable practice may be in accordance with Pat. No. 2,305,999, granted to Alwin G. Steinmayer and William E. Krueger on December 22, 1942, and assigned to the same assignee as the present invention. Although a completed coil and core assembly will be referred to hereinbelow, it will be obvious that the coils **2** may be individually impregnated under the novel process. When the coils are impregnated individually, they may be assembled on a suitable core structure (not shown) at any stage of the process according to the preferences of the manufacturer. After fabrication, the coil and core assembly is cleaned free of all dirt, dust, lint and metallic particles. Tape, leads and the like, are secured and positioned properly, in order that the appearance of the unit after the varnish stage, as will be hereinafter described, will be neat and clean.

The assembled core and coil units are first subjected to a varnish-dip operation. This consists merely in immersing the entire assembly in an open vessel containing the desired varnish mixture. No auxiliary evacuating means or pressure mechanism is required. The assemblies are immersed in the varnish to a depth sufficient to completely cover the coils **2**. All materials and varnish may be kept at room temperature.

A preferred heat-reactive varnish is an oil-modified phenolic, although other types may serve equally well; such as those of styrene-modified polyester varnishes or alkyds, etc. The main factor is that it be reactive at relatively low temperatures to avoid heat damage to insulated portions. Immersion time is relatively short, as may be typically illustrated by the following table:

Transformer Rating	Varnish Immersion
1½ to 7½ kva	45±15 seconds.
10 to 25 kva	2 minutes, −0+15 seconds.
37½ to 100 kva	4 minutes, −0+15 seconds.

The above immersion periods permit the outside two or three layers of insulation and windings in the coils to be completely impregnated and the sides of the coil insulation (coil ends) to be impregnated approximately ¾ to 1″ deep. For further illustration, reference should be had to Fig. 1 wherein the coil **2** is shown greatly enlarged. The magnet winding wire **6** is preferably covered with insulation **7**, and the winding convolutions wrapped exteriorly with an insulating tape **8**, preferably of a fibrous material such as cotton or the like. It will be apparent that the varnish impregnant **5** is permitted to penetrate only the top winding layers. The varnish impregnated coil is next removed from the varnish and preferably suspended above the varnish tank for 5± one minute, in order to permit drainage of excess varnish. Inspection of varnish operations is performed during this drain period. The preferred varnish contains from 40% to 50% volatiles for reasons hereinafter stated.

After draining, and preferably within three hours, the units are placed in a preheated baking or curing oven. The oven temperature is preferably held at 275±5° F. This temperature is preferable, in that it is proper for curing the varnish **5**, and at the same time, is low enough to prevent injury to insulation.

Fig. 2 illustrates the manner in which the varnish volatiles **10** are driven off during baking operations to provide a porous structure with cavities **11** in the relatively thin varnish layer. The cavities **11** which extend through the layer are utilized to provide escape passages for moisture included in the coil insulation

and leads during the baking or curing stage. It is preferable to provide ovens which have a high-velocity air movement and a high percentage of air exchange. The curing assemblies are spaced in the ovens to permit adequate air flow about all of the surfaces. A high exchange of air; that is, a constant supply of fresh, dry air, provides a dry atmosphere inside the oven, which accordingly lowers the relative humidity. This high velocity air movement also speeds the drying of the insulation, inasmuch as water vapors given off are also quickly carried away.

Long curing or baking cycles are not necessary as with ordinary varnish or resinous impregnation, because the superficial varnish layer does not penetrate the internal mass of the coils. Also, long curing cycles at elevated temperatures are apt to provide a brittle varnish layer. A brittle structure would have none of the desirable short circuit-strength characteristics. The governing factor of the curing operation is actually the time required to dry the insulation, which will be more than sufficient to cure the superficial varnish layer. As an example, oven baking times range from 12 hours for 1½ kva. transformers to 20 hours for the 100 kva. units. It will be apparent also that the baking times are dependent upon the various seasons of the year.

The next step in this impregnation process is the all-important cooling stage. The impregnated core and coil assembly is transferred to an air-conditioned dry room, where it is permitted to rest until the core and coil assembly has cooled to a preferable maximum temperature of 140° F. The maximum time permitted for each unit to be exposed to untreated air is preferably 6 minutes. Obviously, the core and coil assembly may be placed in its own tank, tightly covered, to cool to the preferred temperature. The warm atmosphere will prevent entrance of water vapor from the air, in addition to the tightly sealed cover (not shown). However, to facilitate production, it is preferred to use the air conditioned room. The preferred normal operating atmosphere of the air-conditioned room is 90° F. with a relative humidity at not higher than 15%. The maximum acceptable relative humidity is preferably 20%.

After the assemblies have cooled to the desired temperatures, they are placed in a tank (not shown) of the proper classification (if this has not been previously done), all fittings are secured, and the various openings in the tank are completely closed and gasketed.

The above mentioned co-pending application, Serial No. 223,263, discloses an impregnation method which includes a short varnish dip after an initial dry baking operation; a curing or baking operation, followed by an immediate immersion of the unit in a previously oil-filled transformer tank. This obtained good results, with one exception. That is, the immediate immersion of the hot unit into room temperature, or even warm transformer oil, caused sufficient strain in the magnetic core of steel to increase core loss. It was also learned that the immediate immersion of hot varnish into oil lessened the oil-proofness of the varnish. This air-conditioned cooling stage was invented as a means of overcoming these disadvantages.

The final stage of the novel process comprises an oil impregnation, illustrated in Fig. 3. Preferably, this impregnation is accomplished under evacuated conditions. The operation is preferably started within one-half hour after the transformer is removed from the dry room. The cover of the transformer (not shown) is removed, and the special impregnating cover (not shown) is immediately placed thereon. The impregnating cover is provided with fittings for oil feed and air evacuation, respectively. Vacuum is now applied to the tank, and is preferably kept at a 5 mm. mercury absolute pressure, or less. The vacuum is applied to the completely dry transformer for a period prior to admission of the dielectric oil impregnant to remove entrained air. After the dry evacuation period is completed (from 10 minutes to one hour, depending upon the size of the transformer), oil is permitted to enter the transformer case.

The transformer dielectric oil **20** used is necessarily in a very dry state. The water content prior to oil-fill is preferably kept to less than 30 parts per million. The vacuum is maintained throughout the filling operation, and retained for some time after the oil-fill has been completed. This is not necessarily a drying operation, as all of the insulation has been dried prior to cooling in the air-conditioned room, with the operating area being maintained at this dryness until the transformer reaches the vacuum stage. The vacuum merely removed all of the residual air in order that it may be replaced with oil at the proper time, and under high vacuum conditions. The oil **20** is supplied through a metering device (not shown) under the high vacuum, and in an amount nearly equal to the desired requirements. After completion of the oil-fill, the vacuum is broken gradually, in order that a fog is not created within the transformer casing.

Attention is directed to Fig. 3 which illustrates one phase of the dual characteristics of the varnish cavities **11**. After the varnish **5** has been cured, the cavities remain and are used as passages for evacuation and oil impregnation. In this manner, a complete saturation of oil is assured accompanied by high surge strength.

After the vacuum has been broken, the transformer cover or hand-hole cover is securely fastened to the casing to replace the special impregnation cover. The special cover is permitted to remain on the tank in proper placement at all times, except when a specific operation involving casing, testing, or inspection is required. If there is any need for an addition of transformer oil **20** after the vacuum oil-fill, this operation may be accomplished by a properly designed valve (not shown) which permits oil to enter beneath the level of the oil contained in the transformer, thereby preventing introduction of air.

After the transformers have been properly covered with the permanent tank cover (not shown), they are then electrically tested in accordance with established standards, after which the unit is transferred to the crating and shipping station (not shown).

The relatively short varnish dip permits only a superficial coating of varnish **5** to penetrate the coil windings, whereas the oil impregnation penetrates the void cavities **11** in the varnish layer **5** to the innermost layer of the coil. The combination of the protective vise-like envelope of varnish and the deep penetration of the oil impregnation acts to provide a transformer core and coil assembly that has a maximum short-circuit strength and a surge strength at least as high as one treated with oil alone. This novel method derives the best of both the old system of oil impregnation and of varnish impregnation, without partaking of any of their inherent disadvantages.

The temperatures used for drying of insulation and curing of varnish is kept reasonably low, in order that there will be no deleterious effect upon the insulation during curing or baking. The outside insulation and winding layers are protected by the wet varnish from heat damage until the varnish has hardened. In addition, the internal insulation of the coil is protected by the varnished external layers, which acts as a heat shield until the assembly slowly warms to predetermined curing temperature.

The casing operation which may be performed under the very dry atmosphere of the air-conditioned room offers the distinct advantage of cleaner transformer assemblies produced in workman-like manner. Assemblers are not required to do the casing operations under oil. There is no perspiration or condensation that might spoil the work performed. The high vacuum maintained at the oil-fill station reduces residual air to a minimum. Because all entrained air is removed, the unit will have a very high resistance to the formation of corona. One should not underestimate this benefit, as corona rapidly deteriorates insulation. Another added benefit as a result of this operation is that any unit able to withstand the vacuum, will obviously be leakproof.

Another important advantage derived from the novel method is the fact that the power factor of transformers so produced is uniformly low regardless of atmospheric moisture conditions during manufacture. This low power factor is an expression of the optimum dryness of all the insulation, including the properly dried coil insulation and the transformer oil which is maintained in a very dry state.

It will be apparent that the expression "transformer" as used throughout this specification is to be construed in

its broadest sense to include any electrical induction apparatus utilizing impregnated winding assemblies.

It will be apparent that there has been provided a novel transformer assembly produced by a new and improved method of impregnating transformer coil and core assemblies, which method provides the advantages of maximum short circuit and surge strength, maximum resistance to corona, minimum power factor commensurate with insulation life, and minimum weight of varnish; and which assembly is further characterized by having any of its magnetic steel portions substantially strain-free with minimum core losses.

I claim:

1. The process of impregnating a porous conductive coil for an electrical induction apparatus, said coil having outer and inner windings, which consists in immersing said coil containing occluded moisture in a heat-reactive varnish mixture containing volatile varnish solvents for a time sufficient to impregnate only the outer windings with a varnish layer, removing and draining said coil from said mixture, heat curing said varnished coil to evaporate said volatile solvents from said varnish layer to leave void spaces therein, to evaporate said occluded moisture from said coil through said void spaces, and to provide said varnish layer with a non-brittle texture; and impregnating said coil in a dielectric oil to fill the void spaces of said varnish layer and the interstices of the inner windings of said coil.

2. The process of impregnating a porous conductive coil for an electrical induction apparatus, said coil having outer and inner windings, which consists in immersing said coil containing occluded moisture in a heat-reactive varnish mixture containing volatile varnish solvents for a time sufficient to impregnate only the outer windings with a varnish layer; removing and draining said coil from said mixture; heat curing said varnished coil to concurrently evaporate said volatile solvents from said varnish layer to leave void spaces therein, to evaporate said occluded moisture from said coil through said void spaces, and to provide said varnish layer with a non-brittle texture; cooling of said varnished coil to a predetermined maximum temperature in a relatively dry atmosphere; and impregnating said coil in a dielectric oil to fill the void spaces of said varnish layer and the interstices of the inner windings of said coil.

3. The process of impregnating a porous conductive coil for an electrical induction apparatus, said coil having outer and inner windings, which consists in immersing said coil containing occluded moisture in a heat-reactive varnish mixture containing volatile varnish solvents for a time sufficient to impregnate only the outer windings with a varnish layer; removing and draining said coil from said mixture; heat curing said varnished coil to concurrently evaporate said volatile solvents from said varnish layer to leave void spaces therein, to evaporate said occluded moisture from said coil through said void spaces, and to provide said varnish layer with a non-brittle texture; permanently positioning said varnished coil in a covered tank-like vessel to cool said apparatus to a predetermined temperature in a relatively dry atmosphere; and impregnating said coil in a dielectric oil to fill the void spaces of said varnish layer and the interstices of the inner windings of said coil.

4. The process of impregnating a porous conductive winding coil for an electrical induction apparatus, said coil having outer and inner windings, said coil containing occluded moisture in a heat-reactive varnish mixture containing volatile varnish solvents for a time sufficient to impregnate only the outer windings with a varnish layer; removing and draining said coil from said mixture; heat curing said varnished coil to concurrently evaporate said volatile solvents from said varnish layer to leave void spaces therein, to evaporate said occluded moisture from said coil through said void spaces, and to provide said varnish layer with a non-brittle texture; cooling of said varnished coil to a predetermined maximum temperature in a relatively dry atmosphere; and impregnating said coil under evacuating conditions in previously dried dielectric oil to fill the void spaces of said varnish layer and the interstices of the inner windings of said coil.

5. The process of impregnating a porous conductive winding coil for an electrical induction apparatus, said coil having outer and inner windings, which consists in immersing said coil containing occluded moisture in a heat-reactive, oil-modified phenolic varnish mixture containing volatile varnish solvents for a time sufficient to impregnate only the outer windings with a varnish layer; removing said coil from said mixture; heat curing said varnished coil to concurrently evaporate said volatile solvents from said varnish layer to leave void spaces therein, to evaporate said occluded moisture from said coil through said void spaces, and to provide said varnish layer with a non-brittle texture; and impregnating said coil in a dielectric oil to fill the void spaces of said varnish layer and the interstices of the inner windings of said coil.

6. The process of impregnating a porous conductive winding coil for an electrical induction apparatus, said coil having outer and inner windings, which consists in immersing said coil containing occluded moisture in a heat-reactive, styrene-modified polyester varnish mixture containing volatile varnish solvents for a time sufficient to impregnate only the outer windings with a varnish layer; removing said coil from said mixture; heat curing said varnished coil to concurrently evaporate said volatile solvents from said varnish layer to leave void spaces therein, to evaporate said occluded moisture from said coil through said void spaces, and to provide said varnish layer with a non-brittle texture; and impregnating said coil in a dielectric oil to fill the void spaces of said varnish layer and the interstices of the inner windings of said coil.

7. The process of impregnating a porous conductive winding coil for an electrical induction apparatus, said coil having outer and inner windings, which consists in immersing said coil containing occluded moisture in a heat-reactive, alkyd-type varnish mixture containing volatile varnish solvents for a time sufficient to impregnate only the outer windings with a varnish layer; removing said coil from said mixture; heat curing said varnished coil to concurrently evaporate said volatile solvents from said varnish layer to leave void spaces therein, to evaporate said occluded moisture from said coil through said void spaces, and to provide said varnish layer with a non-brittle texture; and impregnating said coil in a dielectric oil to fill the void spaces of said varnish layer and the interstices of the inner windings of said coil.

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