June 13, 1950 H. J. KAUTH 2,511,436

METHOD FOR INSULATING ELECTRICAL EQUIPMENT

Filed Jan. 11, 1946

Fig. 1.

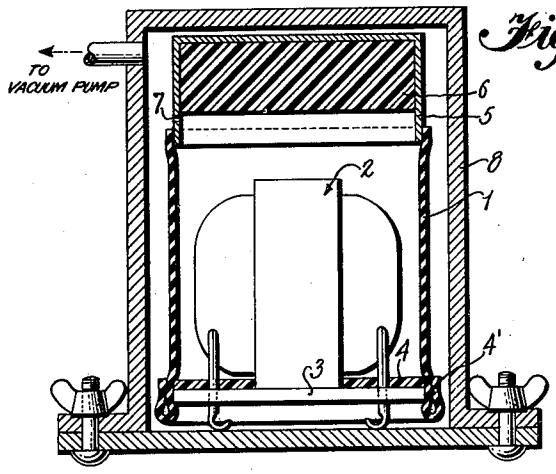
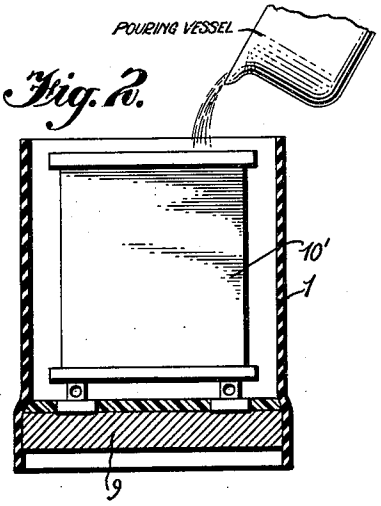


Fig. 2.



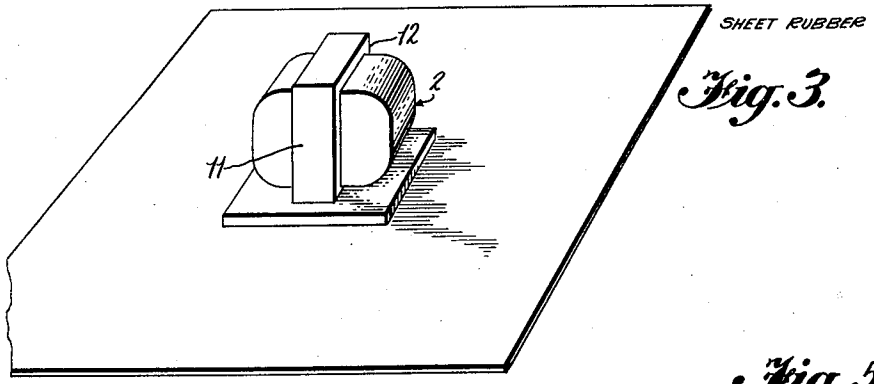


Fig. 3.

Fig. 4.

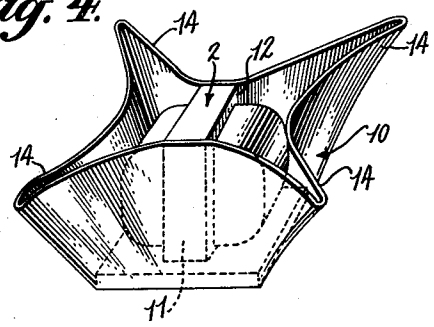
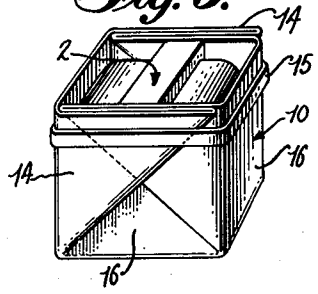


Fig. 5.



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METHOD FOR INSULATING ELECTRICAL EQUIPMENT

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5 Claims. (Cl. 18—59)

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This invention relates to a process for insulative electrical equiment such as coils, transformers, condensers and the like.

It is an object of the present invention to provide a process for producing electrical equipment which is impregnated with and encased by a tough, mechanically strong, water-resistant compound which has the required electrical characteristics and which is self-supporting at elevated temperatures without the aid of any retaining case or container.

It is a further object of this invention to provide a process for completely embedding electrical units in an insulating compound which may be converted by heating or by the use of catalysts into a homogenous, non-thermoplastic, bubble-free mass, having great resistance to mechanical and thermal shock and being particularly effective in excluding moisture from the embedded electrical equipment.

It is a still further object of the invention to provide a process for producing the equivalent of known hermetically sealed equipment which is "potted" in a metal or plastic case, but with a saving in weight and space through the elimination of the retaining case.

A more specific object of the invention is to provide a process for producing electrical equipment embedded in an insulating compound as above described, in which the impregnating and encasing body of compound is solidified about the equipment in a flexible and extensible sleeve or boot, which is removed from the solidified body by pulling it away from the surface thereof.

Other objects of the invention will appear as the following description of a preferred and practical embodiment thereof proceeds.

In the accompanying drawing:

Figure 1 is a diagrammatic vertical section showing the mold assemblage in a vacuum chamber;

Figure 2 is a diagrammatic vertical section indicating the process applied to a transformer which has no terminal board, and in which the vacuum step is omitted;

Figure 3 is a perspective view of the transformer, positioned upon the unfolded mold sheet;

Figure 4 is a similar view showing the mold sheet in an intermediate stage of folding;

Figure 5 is a similar view showing the mold sheet in its final folded position with respect to the transformer, and suitably secured.

It has been customary practice to treat such electrical equipment as coils, transformers, condensers and the like with some sort of varnish,

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wax, asphalt or resinous compound, in order to exclude moisture from entering and destroying the electrical characteristics of the equipment. In some cases the article to be insulated is simply immersed in a molten bath of wax or resin compound, removed and allowed to drain in order to remove excess material. In other cases the article may be immersed in a varnish, particularly one of the heat-reactive or thermo-setting types, then drained and baked to remove solvent and effect conversion of the residue to the insoluble, non-thermoplastic condition. The use of vacuum to remove air and moisture from the interior of the equipment prior to immersion in the insulating material and the use of atmospheric or super-atmospheric pressure to effect complete saturation of the article are well known procedures which have been in common use in the industry.

Where maximum protection against moisture is required, the usual procedure has been to place the equipment, for example, the transformer, into a metal container, and to then fill the container with some insulating compound so that the interstices of the equipment are completely filled and in addition there is a relatively thick layer of compound between the transformer and the metal container. Such "potted" equipment has been very satisfactory where excess weight and space have not been important factors. However, for air-borne equipment and for many other uses, the weight and volume of such equipment preclude its use, and equipment which is equivalent in performance but lighter in weight and of smaller dimensions, is needed. The present invention provides such equipment.

In this process, referring to the drawings, a flexible extensible sleeve 1, of rubber or like material, is fitted to the electrical device to be insulated, so as to form a temporary retaining mold which holds the insulating compound in place during its conversion from the liquid to solid state. In Figure 1 of the drawing, the electrical device 2 is a transformer having a terminal board 3, which extends on all sides beyond any other cross-section of the transformer parallel thereto. The sleeve 1 is slightly smaller than the terminal board, so that its lower end is stretched to tightly embrace the terminal board, to the edges of which it clings with resilient pressure. The sleeve is preferably pulled a slight distance below the terminal board and the edges turned up, as at 4', affording an initial fingerhold to facilitate peeling the sleeve off from the finished product. This expedient is a mere optional de-

tail and is not material to the broader phase of the invention. The sleeve extends above the electrical device and is spaced from all parts of it which lie above the terminal board.

The sleeve 1 should preferably have the same general cross sectional shape as the terminal board; for instance, if the terminal board is rectangular, the sleeve should generally be rectangular, although a cylindrical sleeve may be employed. If the terminal board is rectangular but the electric device above it is cylindrical, then a cylindrical sleeve may be preferred, to fit coaxially in spaced relation to the cylindrical part of the apparatus, the lower end being distorted by stretching to embrace the terminal board. This expedient calls for the use of less of the insulating compound.

The insulating compound when in fluid state, must be of very low viscosity in order to permit the voids and pores in the electrical equipment to be thoroughly impregnated by it. A fluid of such low viscosity would be subject to leak more or less through the joint between the sleeve and terminal board. Therefore, a small quantity of high viscosity thermosetting varnish which sets at a temperature somewhat, but not necessarily a great deal, above the boiling point of water, is introduced into the sleeve to form a layer about one-thirty second of an inch thick on the inner surface of the terminal board, sealing the joint between the terminal board and sleeve. In Figure 1, this layer of varnish is indicated at 4. A can 5, which may be a paper receptacle open at one end, containing a solid mass of the thermosetting insulating material 6 in adherence thereto, enough to fill the sleeve to a level above the top of the transformer 2, is frictionally fitted in, or otherwise supported at the upper end of the sleeve in inverted position, provision being made to permit evacuation of air from the sleeve, such as a perforation 7, at the side of the can outside of the zone occupied by the insulating compound.

This assembly is now placed in a vacuum chamber 8, in which a vacuum of twenty inches to twenty-eight inches is drawn, and to which heat is applied. As the temperature rises, it drives out air from the electrical equipment and volatile solvent from the layer 4 of thermosetting varnish. When the temperature has risen above the boiling point of water, the moisture in the transformer is evaporated, the air, moisture and solvent vapor from the varnish being evacuated.

As the temperature progressively rises, first the layer of thermosetting varnish sets solid, then the insulating compound 6 in the can 5 melts and discharges into the sleeve 1.

At this point the vacuum is released and replaced by atmospheric, or higher pressure, if desired, within the vacuum chamber. This forces the low viscosity fluid into all the interstices of the transformer, including the pores vacated by the air and moisture. Upon further rise in temperature, the insulating compound sets into a solid.

The assembly is now taken from the vacuum chamber, the empty can 5 removed and the assembly transferred to a curing oven. When curing is completed, the sleeve 1 is removed by pulling or peeling it progressively away from the surface of the solidified insulating compound that completely embeds the transformer.

The final shape is given to the insulating body by trimming or cutting with a knife, after which it is coated with one or more coats of a moisture impervious varnish.

Since there is no need for the vacuum equipment after the insulating compound has melted down and filled the sleeve so that the transformer is completely immersed and the insulation material has become solidified, the practicability of immediately removing the assemblage from the vacuum chamber and finishing the curing in an ordinary air oven is of great advantage, since most insulating plants have very limited capacity in the expensive vacuum impregnators, but have plenty of capacity in air ovens. Because the curing of the compound is usually a slow process, requiring several hours, the scarce and expensive vacuum equipment would be tied up unduly were it necessary to do the entire curing in that equipment.

The step of placing the container filled with the solid insulating compound in inverted position at the top of the sleeve and allowing the compound to melt and fill the sleeve while the assembly is under vacuum, is probably the only practical method for vacuum impregnation of the electrical apparatus with a rapidly setting solid heat reactive compound which can be melted and maintained in molten condition only for a short time period before conversion to the infusible state occurs. All of the known methods of the vacuum impregnation require either the use of heat reactive materials in solution, in which a low temperature must be used, or nonheat reactive permanently thermoplastic solid compounds which may be maintained at elevated temperatures for long periods without risk of gelling in the equipment.

A variation of the above process consists in setting the varnish layer 4 and driving out the moisture by heating the assembly to the setting point of the varnish before it is put into the vacuum chamber, and placing it in the vacuum chamber while still hot, the process from that point on, being as previously described. If the heat setting of the sealing layer 4 is done outside of the vacuum chamber, it is not essential that the sealing compound employed have a setting point below the melting temperature of the impregnating and embedding compound.

The process may be carried out with transformers having no terminal board, in which the terminals connected to the ends of the windings are in substantially a common plane, by providing a plug of suitable material such as wood, of a suitable size and shape somewhat greater than the largest cross-section of the transformer in a plane parallel to the plane of the terminals. Such an arrangement is shown in Figure 2, the plug being indicated at 9. After the sleeve has been placed in position with respect to the plug, the transformer 10 is placed within the sleeve, the terminals resting on the plug. The high viscosity sealing varnish is then introduced, and from this point the process is completed according to either of the methods previously described. When the curing is completed, the sleeve is removed, the plug cut off, and the solid insulating compound on the lower face of the embedded transformer cut away to sufficiently expose the terminals. In this form the solidified insulating compound itself constitutes means for rigidly supporting the terminals and effectively sealing off any leakage path which might enter the apparatus along the surface of the terminals, where a terminal board is employed through which the terminals extend.

An alternative method is to apply the sleeve to the terminal board in the manner described,

then to pour directly into the sleeve the requisite amount of sealing varnish and insulating compound, then to place the assemblage in the vacuum chamber and apply the vacuum. The air which is evacuated by this method causes some foaming in the compound, but this disappears entirely during the subsequent heating, before solidification of the compound takes place.

In some instances, where the electrical device will be used in situations in which the ultimate degree of insulating perfection is not required, any one of the above methods may be simplified by omitting the vacuum step, by simply setting up the transformer in the flexible sleeve, as described, the high viscosity sealing varnish being used to seal the joint between the sleeve and terminal board or plug, heating the assemblage to set the varnish, and to drive out air and moisture from the apparatus, and then pouring into the sleeve the insulating compound, in low viscosity fluid state, as indicated in Figure 2, after which the assemblage is heated to set the insulating compound, the curing then completed and the sleeve removed.

An appreciable part of the cost of the methods employing a tubular sleeve is involved in the time required in placing the sleeve about the equipment to be embedded, and in peeling it away from the molded mass. This time factor can be considerably reduced by substituting for the tubular sleeve a flat sheet of flexible material such as sheet rubber. This variant of the invention is best adapted to electrical equipment which has at least two opposite vertical flat sides extending above the terminal board.

The equipment is set in the middle of the sheet 10, as shown in Figure 3. Then the free margins of the sheet are drawn up vertically against the four edges of the terminal board, as shown in Figure 4, to form a container, the opposite sides being pressed against the opposite flat sides 11 and 12 of the equipment. Then the corner flaps 14 are folded along lines perpendicular to the plane of the terminal board and flat against the flat sides of the equipment, as shown in Figure 5. A retaining band 15 is then slipped over the assemblage, bearing against the flat folded corner flaps to hold them in position. The flexible sheet should be of such size that the corner flaps when folded will be of the same height as the four rectangular side walls 16 of the container. In such a construction there can be no leakage of compound from the mold, which obviates need of employing the sealing varnish above the terminal board.

This method has the advantage that after the first time the flexible sheet is used, the creases at the folds are fixed in by the heating and on subsequent use to sheet practically falls into place and can be applied to the unit in less time and with greater facility than a sleeve which has to be stretched on and sealed.

After the sleeve has been taken off, the molded body encasing the transformer has one or preferably a plurality of thin coatings of a highly impervious varnish or lacquer applied thereto. The value of such coating depends upon its continuity. The molded body resulting from the process of the present invention presents a smooth contour which assures the continuity of the varnish or lacquer coating, as contracted with the crannies, sharp edges and corners, if coating of the electrical device is attempted in the absence of the molded encasement. The difference in the continuity of the coating applied to the molded

compound, and over the electrical device itself, is so great that if the molded compound had no function except to provide a smooth base for the coating, it still would be worth while. Actually the molded compound and the outer coatings cooperate to produce the excellence in the overall insulation. The application of this final varnish or lacquer coating is done in the conventional way by dipping and baking.

It is essential that the retaining sleeve have greater extensibility than the insulating compound in its cured state. I have found that compounded natural rubber, neoprene, GR—S, GR–E, Thiokol and highly plasticized plastomers such as polyvinyl chloride can be used for the sleeve material but natural rubber compounds are preferred especially where the insulating compounds are cured by heating, because natural rubber compounds can be made with greater heat resistance than the others mentioned, and sleeves of natural rubber can therefore be re-used a greater number of times before deterioration from heating makes them useless.

The fact that the sleeve used in the process has a much greater extensibility than the recommended compounds have after they are cured, makes it possible to strip off the sleeves notwithstanding a certain amount of adhesion between the compound and the sleeve. However, in some cases it is desirable to reduce the adhesion between the compound and the sleeve to the lowest possible value and this can be done by painting the inside of the sleeve with a solution of water-soluble soap and allowing this coating to dry before using the sleeve.

The process is adaptable to the use of a wide range of insulating compounds, the principal requirement being that the compound selected shall contain no volatile solvent which would form bubbles during the curing, and that no volatile by-product capable of forming bubbles be evolved during the curing. Materials which convert to the cured state entirely by polymerization, and those which evolve gas only in the early stages of curing are satisfactory.

Examples of eligible compounds include:

Permanently fusible acid condensed phenyl aldehyde resin.

Catalyzed China-wood oil compound.

Sulphur or sulphur-chloride "vulcanized" oils.

Styrene-divinyl benzene copolymers which are only partially polymerized before use, containing polymerization catalysts.

Phenolated drying oils made heat-reactive by the inclusion of hexamethylenetetramine, quinone, anthraquinone, choranil, etc.

Maleic polyesters such as diethylene glycol maleates, with added benzoyl peroxide.

Glyceryl phthalate furfural compounds.

Phenolic resin-oil compounds.

Partially polymerized vinyl compounds, such as vinyl acetate, vinyl chloride, acrylic acid esters and copolymers of such compounds with catalysts added.

Sulphur-treated drying oil alkyd resin.

Not all of the above mentioned compounds cure to a truly infusible condition, but they are nonetheless workable if they cure to a solid which has a thermal softening point well above the operating temperature range of the electrical equipment on which they are used. This is generally under 275° F.

Sealing varnishes should preferably be heat-reactive materials which convert to the infusible condition upon heating, but materials which,

although fusible at high temperatures, do not melt and flow at the temperature used for curing the compound may also be used. In the heat-reactive class such materials as phenolic varnishes, alkyd and urea-modified alkyd varnishes are usable. In the non heat-reactive class cellulose acetate, polyvinylchloride-acetate copolymers, ethylcellulose, and similar materials could be used, the essential requirements being that the solution of any of the above materials in volatile solvent be of high viscosity and that the material itself be of molecular weight and viscosity grade which places its softening point above the curing temperature which is to be used. Shellac, with or without the addition of catalysts to accelerate its conversion to the infusible state, is also useful since it does not become fluid enough to flow at the temperature at which the curing of some of the insulating compounds takes place.

Some of the insulating compounds may be made suitable sealing varnishes by treating them to increase the viscosity. For example, an insulating compound may consist of:

	Pounds
A permanently fusible acid-condensed, phenol aldehyde resin	100
Raw linseed oil	150
Hexamethylenetetramine	5

prepared by heating the oil and resin to 550° F., and holding at that temperature until the compound shows clear solubility when tested with xylol. It is then cooled to 250° F. and the hexamethylenetetramine added. Reaction is stopped by cooling as soon as the hexa is completely dispersed.

To convert this into a sealing varnish the heating is continued after the hexa is dispersed until a very high viscosity is obtained, the compound being then thinned to proper pouring consistency, with benzol, toluol or xylol.

Impervious coating varnishes for use on the outside of the molded body of insulating compound may be air drying or baking varnishes. Generally the varnishes which are baked have a greater density and are less permeable to moisture than the air dried materials. The baking materials should be chosen from the heat-reactive classes and should include phenolic-oil, oil modified alkyd, and phenolic-modified alkyd, resins. The air drying materials may be either varnishes or lacquers. One air drying varnish which has a low water vapor diffusion constant is made from paraphenyl phenol-formaldehyde resin cooked in China-wood oil.

In the lacquer classification, solutions of polystyrene and of polyvinylchloride-acetate copolymers are usable, since both of these materials have good impermeability to water.

While I have in the above description disclosed what I believe to be a preferred and practical embodiment of the invention, it will be understood by those skilled in the art that the technique and sequence of the process steps, as well as the details of construction and the materials employed, may be varied to suit the exigencies of use without departing from the scope of the invention.

What I claim as my invention is:

1. The process of insulating electrical equipment such as coils, transformers, condensers and the like, comprising positioning a mold of flexible extensible material about said equipment, placing a vessel above said mold with the contained equipment, containing a quantity of unmelted thermo-setting insulating compound and having an opening in its bottom position to discharge the insulating compound when in molten condition into said mold, surrounding the above instrumentalities by a vacuum chamber, drawing a high vacuum in said chamber, applying heat to said chamber to melt the insulating compound in said vessel and effect its gravitational transfer to said mold while under vacuum, releasing the vacuum while said compound in said mold is in molten condition to permit atmospheric pressure to cause the molten compound to penetrate the voids in the equipment, permitting the compound to set, and finally removing said mold by pulling it away from the surface of the set molded body of insulating compound.

2. The process of insulating electrical equipment such as coils, transformers, condensers and the like, comprising positioning a mold of flexible extensible material about said equipment, placing a vessel above said mold with the contained equipment, containing a quantity of unmelted thermo-setting insulating compound and having an opening in its bottom positioned to discharge the insulating compound when in molten condition into said mold, surrounding the above instrumentalities by a vacuum chamber, drawing a high vacuum in said chamber, applying heat to said chamber at a temperature sufficiently high to melt the insulating compound in said vessel but not high enough to cause it to set, and effecting its gravitational transfer to said mold while under vacuum, releasing the vacuum to permit atmospheric pressure to cause the molten compound to penetrate the voids in the equipment, further heating the insulating compound in said mold to cause it to set, and finally removing said mold by pulling it away from the surface of the set molded body of insulating compound.

3. The process of insulating electrical equipment such as coils, transformers, condensers and the like, comprising placing the equipment upon the middle of a flexible sheet of rubber or like material, folding up said sheet from opposite sides into surrounding relation to said equipment to form a mold thereabout, retaining the mold in up-folded position by a temporary retaining band, placing a vessel above said mold with the contained equipment, containing a quantity of unmelted thermo-setting insulating compound and having an opening in its bottom positioned to discharge the insulating compound when in molten condition into said mold, surrounding the above instrumentalities by a vacuum chamber, drawing a high vacuum in said chamber, applying heat to said chamber to melt the insulating compound in said vessel and effect its gravitational transfer to said mold while under vacuum, releasing the vacuum to permit atmospheric pressure acting against the flexible faces of said mold to cause the molten compound to penetrate the voids in the equipment, permitting the compound to set, and finally removing said mold by pulling it away from the surface of the set molded body of insulating compound.

4. The process of insulating electrical equipment such as coils, transformers, condensers and the like, comprising placing the equipment upon the middle of a flexible sheet of rubber or like material, folding up said sheet from opposite sides into surrounding relation to said equipment to form the sides of an open topped mold, retaining said mold in up-folded position, creating a vacuum about said mold, introducing a solid setting insulating substance in low viscosity liquid state into said mold while under vacuum to com-

pletely submerge the part of the electrical equipment to be insulated, releasing the vacuum while the insulating compound in the mold is still in molten condition to permit atmospheric pressure acting through the flexible faces of said mold to cause the molten compound to penetrate the voids in the equipment, permitting said compound to set solid, and removing said mold by pulling it away from the surface of the set molded body of insulating compound.

5. The process of insulating electrical equipment such as coils, transformers, condensers and the like, having a terminal board which extends on all sides beyond any other cross-section of the equipment, parallel thereto, comprising placing said terminal board upon the middle of a flexible sheet of rubber or like material, up-folding said sheet from all sides against the peripheral edge of said terminal board in sealing relation thereto, and in surrounding relation to said equipment to form the yielding sides of a mold chamber, spaced from that part of the equipment above said terminal board, folding the pleats of fullness produced by said up-folding, flat against said sides, the height of said sides and said folded

pleats being at least as great as the height of the equipment to be insulated, temporarily retaining said sides and pleats in folded position by a retaining band, introducing a solid-setting insulating substance in low viscosity liquid state into said mold chamber to a depth to completely submerge the part of the electrical equipment to be insulated, permitting said substance to set solid, and removing said flexible sheet by pulling it away from the surface of the molded body of insulated substance, thereby permitting it to resume substantially its original flat sheet form.

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