Patented Mar. 7, 1939

2,149,805

UNITED STATES PATENT OFFICE

2,149,805

ELECTRICAL STRUCTURE

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No Drawing. Application October 31, 1935, Serial No. 47,617

7 Claims. (Cl. 91—68)

This invention relates to inherently flexible electrical insulations and to electrical structures such as cables and the like that embody flexible insulations. For this purpose insulation in the form of a varnish coating on cloth, known as varnished cambric is largely used, and the invention more particularly relates to insulation of this character.

Cambric is a term used to designate a fine woven fabric generally of cotton; silk fabric is sometimes employed, and where strength is important linen is substituted; the thickness, flexibility and other characteristics of the fabric depend as well upon the count of the threads and the weave. The fabric can be suitably sized or calendered to remove surface lint; and it is thereupon provided with coatings of varnish for producing the varnished cambric and imparting insulating properties.

In general varnished cambric as heretofore known to the trade is intermediate in its properties between rubber and paper, also used as flexible insulations; it is less flexible and less moisture resistant than rubber but more so in these respects than paper; and it is more resistant to ionization or corona effects than rubber but its dielectric losses are higher than those of paper. As supplied to the trade there are several recognized types of varnished cambric, differing as to the kind of varnish used for coating, and these vary in their properties in accordance with the varnish. One is the so-called yellow cambric in which the varnish applied is prepared by heat-treating a drying oil, chiefly linseed oil, to a definite body and then thinning and adding soluble driers; when a cambric with such a varnish coating is baked and properly conditioned (i. e. moisture removed), it shows a dielectric strength of from 1100–1400 volts per mil and a power factor that varies from 5–6% at 20° C. up to 8–10% at 80° C., though under the varying conditions of humidity in storage the power factor is normally higher in the neighborhood of 12–18% at 80° C.; (specifications prepared by the Insulated Power, Cable Engineers Association on varnished cambric insulated cables call for measurements of power factor at different temperatures, the highest being 80° C.); this type of cambric has fair resistance to heat and good resistance to transformer oils. A second type is the standard black cambric in which the coating composition is produced by blending or cooking a fairly large percentage of asphaltum in a drying oil; when properly conditioned to remove moisture such a coated cambric shows a dielectric strength of 1200–1500 volts per mil and a power factor of 3–6% at 20° C. and 5–7% at 80° C., but the coating is not resistant to transformer oil and becomes brittle on aging and exposure to heat. A third type of varnished cambric that has been proposed is one coated with an alkyd resin composition; this is characterized by a dielectric strength of about 1000–1800 volts per mil and good heat and transformer oil resistance, but resistance to moisture is poor and it shows high dielectric losses, the power factor at 20° C. being about 5–10% but at 80° C. about 25–40%. A comparison of these types of varnished cambric shows that one is superior to another in some respects but inferior in other respects; but common to all is an increase in power factor as the temperature increases.

The present invention provides insulation of the varnished cambric type having as a distinguishing characteristic a low dielectric loss (with a consequent saving in power and an increase in current carrying capacity of a cable) which dielectric loss decreases instead of increases as the temperature approaches 80° C. Since the maximum operating temperature of cables generally is about 80° C., the insulation of the present invention is accordingly characterized by an improvement in operating conditions with the heating of the cable rather than the reverse which normally characterizes other known insulating media.

In addition the insulation of the present invention exhibits a high resistance to the action of transformer oil, it retains its high degree of flexibility upon aging, and samples exposed over a period of three months on a tide range test in salt water have been unaffected thereby. It has a "long time" high dielectric strength which means a saving in size, weight and cost of a finished cable; and it possesses excellent resistance to corona discharge and ionization. In heat resistance it is better than the yellow or black varnished cambric and approaches or equals that of the alkyd resin type; heat resistance is a particularly desirable feature, since the higher temperature the insulation can withstand, the more current the cable is able to carry.

A further characteristic of the film coating obtained by means of this invention is its low acidity and substantially no increase in acidity on aging. Films of linseed oil in contrast increase in acidity and in time become soft and tacky; in this condition they are corrosive to copper.

The foregoing improvements in insulations of the varnished cambric type and structures em-

bodying them are obtained by the employment in the exposed or protective coatings of alkyl- or aryl-substituted phenol-aldehyde resins which possess the characteristic of solubility in vegetable oils and consequently are compatible with drying oils ordinarily used in the preparation of oil varnishes when used in conjunction with drying oils in proportions of one part of the resin to two to six parts of the oil Particularly suitable are aryl-substituted phenol-aldehyde resins such as the phenyl-phenol resins which are completely oil-soluble without modification by rosin or natural resins.

In addition to the foregoing properties it is desirable that the cambric meet requirements as to tearing strength. It has been found that the cambric can be improved in this respect by the application of a primer coat prepared from a resin obtained by esterifying with a polyhydric alcohol the condensation product of a phenol-carboxylic acid with formaldehyde or the like. The preferred form of the invention accordingly includes as a primer coat one containing the esterified product of a carboxyl-substituted phenol reacted with formaldehyde.

In order to provide for lubrication a wax is included in the surface or top coat. A wax found suitable is ceresin wax, particularly in association with a phenyl-phenol or equivalent resin in fatty oil solution. Such a lubricating wax is likewise found effective as an ingredient in the primer coat for waterproofing the fibers, as it "sweats out" upon heating and works into the fibers. Ceresin wax is further found to improve the power factor, causing a decrease of as much as 10%.

An illustration of the preparation of a varnished cambric in accordance with this invention follows in detail. It is to be understood, however, that it is not restricted to the specific embodiment given as illustrations, and is to be given the scope commensurate with the appended claims.

A cambric of woven cotton fabric, suitably sized and/or calendered to remove lint, is given a primer coat by passing through a dipping tank containing a varnish prepared as follows:

A resinous complex is prepared from about 0.55 parts of a polyhydric alcohol, such as glycerol, 4 parts of a natural resin acid such as abietic acid and 1 part of a potentially reactive phenolic polybasic acid previously formed from the reaction of p-hydroxy benzoic acid with formaldehyde in approximately equimolecular proportions; other polyhydric alcohols such as ethylene glycol, pentaerythritol, and other natural resins or resin acids such as rosin, copal, sandarac, capable of forming esters with polyhydric alcohols, and other aromatic hydroxy carboxylic acids such as cresotinic acid, hydroxy napthhoic acid, etc., can be used in whole or in part in preparing the resin; and equivalent methylene-containing agents can be substituted for formaldehyde such as the higher aldehydes, hexamethylenetetramine, acetone, etc., as known to the art and herein designated generally under aldehydes. Substantially 9 parts of the complex is added to 35 parts of linseed oil of a viscosity of about 435 centipoises (Gardner Holdt Standard Body Q). This mixture is heated to 540° F. in the course of one hour and is maintained at this temperature for from 4–7 hours or to a heavy body. Then about 15 parts of tung oil or enough to make the total drying oil content about 50 parts are added which cools the mixture to about 450° F.; tung oil is a relatively faster polymerizing oil than linseed oil initially used in the cooking operation. The proportion of resin to drying oil may be subject to wide variation, as for example one part of resin to 2–6 parts of drying oil, while the drying oil constituents for instance may vary from 100% of one oil as linseed oil to 40% of one oil as linseed oil and 60% of another oil as tung oil. Heat is applied to raise the temperature again to about 500–520° F. whereupon it is permitted to cool to about 450° F., and this step is repeated until a heavy body is obtained. The composition is thinned with about 40 parts of hydrocarbon thinner when its viscosity should be 125–175 centipoises. About .75 part of a drier consisting principally of lead naphthenate including small proportions of cobalt naphthenate and manganese naphthenate is added. The foregoing composition is coated on the cambric and the coated product is baked for about 45 minutes at about 135° C.

A body coat is next applied to the cambric carrying the primer coat, and for this purpose a suitable varnish is preferably prepared from a phenolic resin characterized by inherent solubility in fatty oil and obtained by the reaction of equimolecular proportions with an aldehyde of an aryl-substituted phenol or its homologs as para-phenyl-phenol, dicresol, dithymol, etc. Other resins characterized by inherent oil-solubility and useful in the body coats are obtainable from alkyl-substituted phenols, such as crude cresol mixtures, xylenols, butyl phenol, amyl phenol, benzyl phenol, etc., as well as aryl-substituted phenols and their homologs; and they are preferably reacted with approximately equimolecular or higher proportions of formaldehyde or equivalent. About 9.5 parts of such a resin is cooked with say about 29 parts of linseed oil (Body Q) as before and this is cooled by the addition of about 7 parts of tung oil. The resin-drying oil proportions and the drying oil constituents may be varied as in the primer coating composition. The mixture is heated and again cooled to about 450° F., whereupon 54 parts of hydrocarbon thinner are added together with about .5 part of a drier of similar composition to that used in the primer coat. The viscosity of the varnish should be 125–175 centipoises. Again the coated cambric is baked for 40 minutes at about 135° C. Preferably a third coat of the same body composition as the second is applied and baked.

A top coat or surface coat finishes the varnished cambric. This composition is like that of the body coat but contains about 1⅓ parts of ceresin wax to every 100 parts of varnish which wax is dissolved in the varnish while hot. Other waxes can be used for this purpose such as carnauba wax, paraffin wax, halogenated naphthalenes, etc. This coat is baked for about 40 minutes at about 135° C.

A varnished cambric, prepared in accordance with the foregoing, showed no tendency to crack even when doubled upon itself either with or across the machine direction. Its tensile strength exceeded 3000 lbs. per square inch, and tearing strength on an Elmendorfer tester ranged from 18–26 lbs. Its dielectric strength was 1200–1800 volts per mil; it showed no blistering when submerged in transformer oil for 1 hour at 150° C.; and after heating to 100° C. for 700–900 hours and cooled it did not crack when bent around a 3 mm. rod. The dielectric loss which is usually expressed in the power factor of the material, was remarkably low; at 60 cycles, the pow-

er factor at 25° C. approximated 3–5%, average of 4%, and at 80° C. it was about 1–3%, average of 2%. The acid number of the cambric after exposure of sample to tidal action for 5 months at a temperature averaging about 45° C. ranged from 9 to 10 and the films were hard and intact; in comparison a film prepared from bodied linseed oil and tested at the same time under the same conditions was in a very poor condition, being tacky and eaten away in spots, and had an acid number of over 26.

The effects obtained by the use of these varnishes can also be had in combination with other coating compositions. Thus it is possible to increase the heat resistance by giving the cambric a primer coat with a varnish containing both oil-soluble phenolic resins and oil-modified alkyd resins. For instance, a varnish is prepared similar to that described for a primer coat or that described for the body coat except one-half of the resinous content is replaced by a modified alkyd resin prepared by reacting a polyhydric alcohol, specifically glycerol, with a polybasic acid, for example, phthalic anhydride, and a monobasic fatty acid, as for example, a mixture of the fatty acids derived from cocoanut oil; the fatty acid-modified alkyd resin is added preferably by cold blending it with the primer or body coat composition. Instead of mixing the alkyd resin with a resinous ester or an oil-soluble phenolic resin, one or two coats of a fatty acid-modified alkyd resin varnish can be applied and one or two body or top coats of an oil-soluble resin varnish as herein described applied thereover.

Use of the complex resin esters as derived from a phenol-carboxylic acid in the primer coats is particularly advantageous, since it adds both to the heat resistance and to the mechanical strength of the varnished cambric particularly to the tear strength test, which indicates the ability of the insulation to withstand the stresses and strains incident to bending and twisting of the cable under commercial use. These resin esters are also useful as substitutes or additions in the body coats. Coated cambric can also be made by blending together the varnish as disclosed for use as a primer coat and the varnish as disclosed for use on the body coat in proportions, for example of about equal weight of each varnish and applying three successive coats of this blended varnish and then using the varnish as disclosed for the top coat. On the other hand a varnish prepared from an alkyl- or aryl-substituted phenol can be used for the primer as well as a body coat, particularly when tear strength is not important.

In place of linseed oil and China-wood oil in the various coats it is possible to employ other drying or semi-drying fatty oils as soya bean oil, perilla oil, fish oil, etc. For the purpose of this invention the drying oils should not be blown, and raw oils or oils of low acid number or oils heat-bodied to a viscosity not greater than Body Q (Gardner-Holdt Standard) are desirable. The oils are preferably bodied in the presence of the oil-soluble phenolic resins, since this procedure markedly improves the insulating qualities of the coating.

While the examples disclose the preferred proportions of resin and oil these may be varied within rather wide limits. In general it may be said, however, that the greater the content of those phenol aldehyde resins which are oil-soluble without modification by rosin or other natural resin, the more marked is the improvement in electrical properties particularly dielectric loss, water and weather resistance.

The method of application of the varnishes herein disclosed may be by dipping, spraying, brushing, or by any other convenient means on the cambric or other base material. In the manufacture of electrical structures, such as cable for example, the cambric is wrapped about a conductor or about other insulation and protected by a covering, which can be braid, lead sheath, etc. in the usual manner of building cables; a conductive metallic tape or the like can be included in the covering that is externally applied to the cambric.

Although the improved insulative varnish prepared according to the present invention has been hereinbefore described particularly in its relation to cambric insulated power cables, it is to be understood that its application is not limited to coated cambrics or flexible bases but instead includes other uses of an insulative body such as varnish coatings applied directly to conductive wires and the like without the interposition of a flexible base. The insulating and other properties characterizing the coated bases emanate from the varnish coatings and are accordingly exhibited when the bases are omitted.

We claim:

1. Electrical structure comprising in combination a conductive element and insulation for said element, said insulation comprising a primer coating containing a resinous product selected from the group consisting of fatty acid-modified alkyd resins and polyhydric alcohol-esterified reaction products of phenol carboxylic acids with aldehydes, and a protective coating of a varnish in the proportions of one part of a reaction product of an aldehyde with a phenol substituted by a radical selected from the group consisting of alkyl and aryl radicals to from two to six parts of a fatty oil.

2. Electrical structure according to claim 1 in which the fatty oil in the protective coating is a mixture of oils including not more than sixty per cent of tung oil.

3. Electrical insulation comprising a base, a primer coating on said base and containing a resinous product selected from the group consisting of fatty acid-modified alkyd resins and polyhydric alcohol-esterified reaction products of phenol carboxylic acids with aldehydes, and a protective coating of a varnish in the proportions of one part of a reaction product of an aldehyde with a phenol substituted by a radical selected from the group consisting of alkyl and aryl radicals to from two to six parts of a fatty oil.

4. Electric insulation according to claim 3 in which the fatty oil in the protective coating is a mixture of oils including not more than sixty per cent of a relatively faster polymerizing oil than another oil constituent.

5. Electrical insulation according to claim 3 in which a wax is included as a constituent of a coating.

6. Composition suitable for an electrical insulation coating comprising one part of a reaction product of an aldehyde with a phenol substituted by a radical selected from the group consisting of alkyl and aryl radicals to from two to six parts of a fatty oil, not more than sixty per cent of said oil being tung oil, said composition being of such a nature as to be obtainable in film form characterized by a decreasing power factor when heated from 20° C. up to 80° C.

7. Process of preparing a composition suitable for electrical insulation coating and of such a nature as to be obtainable in film form characterized by a decreasing power factor when heated from 20° to 80° C. which comprises forming a phenolic resin inherently soluble in fatty oil, cooking the resin with a fatty oil bodied to a viscosity not greater than Body Q, adding to the composition a fatty oil that is relatively faster in polymerizing than the initially used oil in a proportion not greater than sixty per cent of the total oil content, said oil being included in the composition in proportion of from two to six parts to each part of resin, and cooking the composition to a desired body.

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