

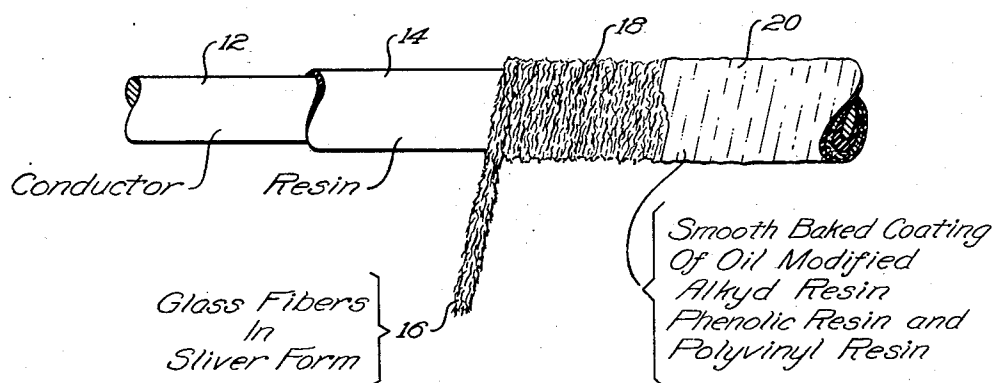
Feb. 20, 1945.

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2,370,046

INSULATED ELECTRICAL CONDUCTOR

Filed March 20, 1942



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2,370,046

INSULATED ELECTRICAL CONDUCTOR

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Application March 20, 1942, Serial No. 435,445

13 Claims. (Cl. 174-120)

This invention relates to electrical conductors carrying electrical insulation. More particularly, the electrical insulation comprises glass fibers and a resinous composition applied thereto to provide for a smooth, highly insulative and impregnated coating on the conductor.

The object of this invention is to provide for applying to glass fibers upon conductors a binder cooperative therewith to produce a smooth-surfaced, tightly adherent insulation having good electrical properties.

A further object of this invention is to provide for applying glass fibers in the form of sliver in combination with a binder to produce a smooth-surfaced, tightly adherent, insulating coating upon electrical conductors.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

For a fuller understanding of the nature and objects of the invention, reference should be had to the single figure of the drawing illustrating an electrical conductor embodying the novel features of the invention.

It has been proposed heretofore to apply glass fibers to electrical conductors to produce insulation capable of operating at temperatures substantially above those at which insulated conductors may be operated at the present time. Since insulation composed only of glass fibers consists of non-porous glass drawn into various lengths with interstices therebetween, the effectiveness of the glass fibers as insulation is determined by the nature of the material in the interstices between the fibers. If better than air insulation is required, it is necessary to impregnate the interstices between the glass fibers with an insulative material.

It has been suggested to use glass fibers in combination with various resinous materials in order to produce a combined electrical insulation having desirable electrical properties. Due to the cost of spun glass fibers, it has been desirable to apply as thin a combination of the glass fibers and resinous impregnating material as possible.

Glass fibers are sold to the trade in two main forms suitable for applying to electrical conductors. Continuous fibers prepared from continuous filaments of spun glass of a diameter of less than 0.002 inch have been used almost exclusively for coating electrical conductors, particularly in the standard magnet wire sizes. One or more thicknesses of the spun glass fibers can be wrapped closely together about the electrical conductor to produce a relatively thin and smooth insulation. The second commercially

available form of glass fibers is sliver. In sliver the glass fibers consist of small lengths of the order of from one inch to eighteen inches combined into a loose mass. When glass fibers in the form of sliver have been applied to electrical conductors, it was discovered that thin layers having a smooth surface have been substantially impossible to produce. The numerous short lengths of glass fibers protrude when the sliver has been applied to the conductor to produce a fuzzy or woolly surface body. When resin is applied to this material in order to impregnate it, the final cured product is exceedingly rough with numerous projecting glass fibers present on the surface. This is a relatively dusty material since the projecting fibers break off. The handling of the material causes itching. Tight coils, for example, cannot be produced from this type of material. Therefore, space efficiency would have to be greatly reduced if glass of the type of sliver were employed upon conductors. On bending the conductors, it was found that the turns of sliver separated readily to expose the bare conductor. Accordingly, the art has been limited to a great extent to the use of the glass fibers in the form of continuous filaments.

In some cases sliver composed of staple fibers is drawn and twisted into what is designated in the art as "staple yarn." Such staple yarn is a tighter twisted product than sliver, but when applied to conductors under prior art practice, it results in the same objectionable roughness and loose, protruding fibers. The present invention contemplates the treatment of staple yarn to produce a satisfactorily smooth and uniform insulation on conductors.

Since synthetic glass fibers consisting of continuous filaments are approximately three times as expensive per pound as compared to the glass fibers in the form of sliver, it is desirable to employ glass sliver for economical reasons. Due to these factors of rough surface and projecting fibers, it has been substantially impractical to employ the glass sliver, in spite of the difference in prices of the material. Burnishing dies and similar apparatus have been relatively ineffective in producing satisfactory surface coatings of glass sliver on conductors.

According to this invention, it has been discovered that certain resinous compositions or combinations of resinous compositions may be applied to glass fibers in the form of sliver to give a product that is so much smoother than the results obtained heretofore with glass sliver that the material may be applied for the same ap-

plications for which conductors covered only with glass fibers consisting of continuous filaments was deemed suitable. In addition, the resinous composition or the successive coatings of selected resinous composition produces a more tenacious adherence of the glass fibers to an electrical conductor, so that the glass fibers will withstand considerable more flexing and bending without cracking or separating from the conductor. In addition, the resinous compositions are exceedingly good electrical insulators, and thereby produce highly effective dielectric insulation when applied to conductors. The combined insulation resists abrasion better than celulosic insulating materials or asbestos coverings. A good indication of the quality of the insulation is secured by hammering two crossed wires. It is difficult to short the wires by the hammering.

It has been discovered that a phenol-formaldehyde resin combined with an oil-modified alkyd resin and a small proportion of a polyvinyl alcohol has certain unexpected characteristics when applied to glass fibers. The material is tenaciously adherent to the glass fibers, and on drying tends to shrink the fibers into a smooth homogenous body of a type desired for surface electrical insulation. As an example of the resinous composition, the following is illustrative.

EXAMPLE No. 1

Phenol and formaldehyde are reacted in proportions corresponding closely to equi-molecular proportions in the presence of an alkaline catalyst. Cresols, cresylic acid, hydroxy benzene and other phenols may be reacted with other methylene bodies than formaldehyde in producing the phenolic resin. When the "A" stage of reaction has been substantially reached, the resin is precipitated in water in order to remove excess phenol. A substantially phenol-free reaction product is more desirable for the purpose of the invention. After purification in water, the phenol-formaldehyde resin is removed and dissolved in solvents therefor. A mixture of ethyl alcohol and ethyl acetate is an example of a suitable solvent.

In another reaction vessel, two parts of phthalic anhydride, glycerol one part, and linseed oil one part, all proportions being by weight, are reacted for about one-half hour at from 180° C. to 200° C. This condensation evolves water. The condensation product should be continually stirred and the temperature increased at the end of the initial period to about 220° C. for from one-half hour to three-quarters of an hour. An oil-modified alkyd resin is thus produced.

The main requirement is that the alkyd resin product be highly flexible when dried in films. To provide for this flexibility effective quantities of fatty oils, drying oils or oil acids should be reacted with a dibasic acid and a polyhydric alcohol. Examples of suitable oils are linseed oil, castor oil, tung oil and ricinoleic acid. The dibasic acids may be succinic, adipic, phthalic or sebacic acids or mixtures thereof. The polyhydric alcohols reacted therewith may be selected from ethylene glycol, glycerol, trimethylene glycol and the like. The proportions of the three reactants may be varied to meet requirements, but generally reacting proportions approximating from equimolar products to the half ester of the dibasic acid with the polyhydric alcohol result in a satisfactory combination for modification with oil.

The substantially phenol-free phenol-formaldehyde resin in the "A" stage is combined with

the oil-modified alkyd resin in the proportion of from 10 to 25 parts of the phenol formaldehyde and from 25 to 100 parts of the oil-modified alkyd resin. With greater proportions of phenol formaldehyde, the resin will produce a much harder resin body or coating after curing by a heat treatment. With the greater quantities of the alkyd resin, a much more flexible and plastic film is produced after curing by heat treatment. Depending upon the fineness of the conductor to which the resin is to be applied and the degree of deformation to which the conductor is to be subjected, the proportions may be varied to meet the flexibility desired in the final resin.

It has been discovered that while this resin composition has good characteristics when applied to glass fibers, the desirable results of this invention are not completely attained unless a polyvinyl alcohol or hydrolyzed polyvinyl ester has been introduced thereto. Therefore, it is important to add polyvinyl alcohol thereto. The following formulation has been found to produce very satisfactory results in combination with the phenol formaldehyde combined with an oil-modified alkyd resin:

Formula

	Per cent
Polyvinyl alcohol-----	1.4
Ethyl alcohol-----	5
Water -----	20.6
Phenolic alkyd varnish in alcohol and ethyl acetate solvent (50% solids)----	73
	100

The composition shown in the formula may be treated with a small amount of wetting agent in order to facilitate homogenizing. The polyvinyl alcohol and the phenolic-oil-modified alkyd resin do not form a true solution, but produce a form of suspension. It should be thoroughly stirred during application. The proportions of polyvinyl alcohol may vary from 2 to 20 parts, while the phenol formaldehyde may vary from 10 to 25 parts, and the oil modified alkyd resin from 25 to 100 parts. All of the parts given are by weight. This combination when applied to glass fibers, particularly in the form of sliver, produces a highly effective coating material which when baked or heat treated draws in all loose projecting fibers and results in a smooth electrical insulation having an attractive appearance.

EXAMPLE No. 2

A mixture of maleic acid, glycol and castor oil, using substantially equal weights of the three, may be reacted at temperatures of about 200° C. for one to two hours, with removal of water vapor to produce an oil-modified alkyd resin suitable for the purpose of this invention. The oil-modified alkyd resin of this example may be combined with substantially phenol-free, phenol formaldehyde in the same proportions as set forth in Example No. 1. The proportions of unsaturated dibasic acid, polyhydric alcohol and oil may be varied widely. In producing oil-modified alkyd resin, the oils which may be employed may include soybean oil, tung oil, fish oils of various types, blown castor oil, or the acids of both drying oils and fatty oils. In general, the oils provide for a more flexible film than the alkyd resin produced from a dibasic acid and polyhydric alcohol alone.

In applying the resinous composition disclosed in the two examples above, the composition including polyvinyl alcohol therein, to conductors, reference should be had to the single figure of the

drawing which is a schematic view of the conductor in various stages of application of the insulation. The conductor 12 is preferably initially coated with a layer of the resinous composition 14 either of the type disclosed in the Examples Nos. 1 and 2, or, in some cases, polyvinyl alcohol alone or any other resinous material capable of adhering to the glass fibers and to the conductor may be applied. The polyvinyl alcohol suitable for the resinous layer 14 may consist of from a 5% to 15% solution of polyvinyl alcohol derived from a polyvinyl ester hydrolyzed to such an extent that it is soluble in a water-alcohol solution. The water-alcohol solution is employed as a carrier or solvent for the polyvinyl alcohol. The glass fibers in the form of sliver 16 are wrapped about the conductor upon the wet or tacky resin coating 14. One or more layers of sliver may be superimposed. Suitable spinning heads for so applying the glass sliver are well known in the art and need not be described here. A layer of glass fibers 18 with numerous projections and having a woolly or fuzzy appearance is produced at this stage since no impregnant has been applied upon the glass fibers.

One of several procedures for applying an impregnating and binding resin to the glass fiber coating 18 may be followed to produce a satisfactory final product. The following procedure has been particularly satisfactory for the purpose of the invention:

TREATMENT No. 1

The resinous composition solution of either Example No. 1 or Example No. 2 containing polyvinyl alcohol is applied, for example, by dipping or pumping onto the wire to the glass fiber layer 18 and baked in standard enameling towers for a fraction of a minute at temperatures of from 300° C. to 600° C. The baking removes the liquid carrier present and cures the resin. While a fairly smooth coating is produced by application of this resin alone, it has been discovered that a subsequent application of polyvinyl alcohol alone produces a somewhat improved product with a much smoother surface with no projections of glass fibers. A 5% polyvinyl alcohol solution in water and ethyl alcohol as the solvent is applied to the conductor and baked at about the same conditions as the composite resinous composition. The conductor will now present an exceedingly smooth surface 20 which is capable of being wound into tight coils or put in motor or generator slots with ease. Substantially no projections of glass fibers will be evident on the surface. The effect is similar to that produced by passing other fibrous materials through burnishing dies.

In some cases, in order to insure a more complete application of impregnating material to the glass coating 18, a second application of the phenol-formaldehyde-oil modified alkyd resin having a small amount of polyvinyl alcohol may be made. After baking, the conductor may be again coated with polyvinyl alcohol alone followed by a final baking to effect a cure. The final product produced after applying the four coatings applied to the glass sliver is an exceedingly desirable form of electrical insulation. Since the resinous composition applied to the glass fibers has approximately 50% solids and even higher, the fill is greatly superior to that produced by other synthetic resins having much lower proportions of solvents. For example, polyvinylal resins have the undesirable characteristic of forming extremely viscous solutions at

low percentages of solid content—8% solid content is about as concentrated a solution of polyvinylal resins which may be effectively applied to members for impregnating purposes. Accordingly, polyvinylal solutions are substantially impractical in producing a well impregnated glass insulation. Furthermore, the smoothing down of the fiber ends is a feature that is only produced by the application of polyvinyl alcohol as such in a coating composition.

TREATMENT No. 2

The glass coating 18 may be satisfactorily treated by applying polyvinyl alcohol solution initially followed by baking to remove the liquid carrier and a subsequent coating of the composition of phenol-formaldehyde, oil-modified alkyd resin and polyvinyl alcohol. Baking after this treatment will produce a conductor that is satisfactory for use, or in some cases, an external coating of polyvinyl alcohol solution followed by a final bake will produce a highly insulated conductor.

TREATMENT No. 3

In some cases, where the resinous solution of phenol formaldehyde and oil-modified alkyd resin contains a relatively large amount of polyvinyl alcohol, two or three successive applications thereof, without applying any polyvinyl alcohol alone, have produced insulation carrying glass fibers in the form of sliver which is satisfactory for the purposes of the invention.

Ordinarily the initial resin application 14 on the conductor is desirable. In some cases it may be dispensed with providing the subsequently applied sliver is thoroughly impregnated down to the conductor to effect adequate bonding.

It will be appreciated that the advantages of the invention are most pronounced when the cheapest commercial form of glass fibers, namely, sliver, is employed in cooperation with the resin. However, the advantages of the resin are so pronounced that, in some cases, it will lend itself to use with other forms of glass fibers, since it effects a good bond between the glass and the conductor as well as being a good impregnant for the interstices between glass fibers. It is of value when used in combination with staple yarn or with continuous filaments. Glass fibers which may be applied in felted form to conductors may be satisfactorily treated by means of the compositions and the selected arrangement of coatings herein disclosed.

It will be apparent that the resinous composition and polyvinyl alcohol alone may be applied as successive coatings to the glass sliver once or in a plurality of successive coatings.

The flexible unitary insulating material produced in the manner set forth above may be applied to electrical conductors having either a stranded core or formed of solid wire.

Since certain changes in carrying out the above process, and certain modifications in the article which embody the invention may be made without departing from its scope, it is intended that all matter contained in the above description or shown in the drawing shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. An insulated conductor comprising, in combination, an electrical conductor, glass fibers in the form of sliver wrapped about the conductor, and a resinous composition applied to the electrical conductor and heat treated to closely bind the glass sliver thereto, the composition im-

pregnating the interstices between the glass fibers to provide for a smooth exterior surface free from projecting glass fibers and to provide for good electrical insulation, the resinous composition composed of an oil-modified alkyd resin, phenol-formaldehyde and hydrolyzed polyvinyl ester.

2. An insulated conductor comprising, in combination, an electrical conductor, glass fibers in the form of sliver wrapped about the conductor, and a resinous composition applied to the electrical conductor and heat treated to closely bind the glass sliver thereto, the composition impregnating the interstices between the glass fibers to provide for a smooth exterior surface free from projecting glass fibers and to provide for good electrical insulation, the resinous composition applied as a plurality of coatings, including an initial coating upon the conductor composed of phenol formaldehyde combined with an oil-modified alkyd resin, subsequent coatings applied to the sliver composed of phenol-formaldehyde combined with an oil-modified alkyd resin and a hydrolyzed polyvinyl ester and coatings of the hydrolyzed polyvinyl ester alone.

3. An insulated conductor comprising, in combination, an electrical conductor, glass fibers in the form of sliver wrapped about the conductor, and a resinous composition applied to the electrical conductor and heat treated to closely bind the glass sliver thereto, the composition impregnating the interstices between the glass fibers to provide for a smooth exterior surface free from projecting glass fibers and to provide for good electrical insulation, the resinous composition applied as a plurality of coatings, including an initial coating upon the conductor composed of from 10 to 25 parts of phenol-formaldehyde combined with from 25 to 100 parts of an oil-modified alkyd resin, subsequent coatings applied to the sliver composed of from 10 to 25 parts of phenol-formaldehyde combined with from 25 to 100 parts of an oil-modified alkyd resin and 2 to 20 parts of hydrolyzed polyvinyl ester and coatings of the hydrolyzed polyvinyl ester alone.

4. An insulated conductor comprising, in combination, an electrical conductor, glass fibers in the form of sliver wrapped about the conductor, and a resinous composition applied to the conductor and the sliver and heat treated to closely bind the glass sliver to the conductor, the composition impregnating the interstices between the glass fibers to provide for a smooth exterior surface relatively free from projecting fibers and to provide for good electrical insulation, the resinous composition composed of a substantially phenol-free phenol-formaldehyde, the reaction product of a dibasic acid, a polyhydric alcohol and an oil, and a hydrolyzed polyvinyl ester.

5. An insulated conductor comprising, in combination, an electrical conductor, glass fibers in the form of sliver wrapped about the conductor, and a resinous composition applied to the conductor and the sliver and heat treated to closely bind the glass sliver to the conductor, the composition impregnating the interstices between the glass fibers to provide for a smooth exterior surface relatively free from projecting fibers and to provide for good electrical insulation, the resinous composition composed of from 10 to 25 parts of a substantially phenol-free, phenol-formaldehyde, from 25 to 100 parts of the reaction product of a dibasic acid, a polyhydric alcohol and an oil, and from 2 to 20 parts of hydrolyzed polyvinyl ester.

6. In the method of applying glass fibers in the form of sliver in combination with a resinous binder and impregnant for the interstices between glass fibers to an electrical conductor to provide for electrically insulating the conductor comprising, applying a sliver of glass fibers to the electrical conductor, applying a hydrolyzed polyvinyl ester in a liquid carrier to the applied sliver, heat-treating the conductor to remove the liquid carrier, applying a resinous composition composed of phenol-aldehyde, an oil-modified alkyd resin and a hydrolyzed polyvinyl ester in a liquid medium, and heat-treating the conductor to remove the liquid medium and to cure the applied materials to produce an insulated conductor.

7. In the method of applying glass fibers in the form of sliver in combination with a resinous binder and impregnant for the interstices between glass fibers to an electrical conductor to provide for electrically insulating the conductor comprising, applying to the electrical conductor a resinous binder capable of adhering to glass fibers, applying a sliver of glass fibers to the electrical conductor upon the resinous binder, applying a hydrolyzed polyvinyl ester in a liquid carrier to the applied sliver, heat-treating the conductor to remove the liquid carrier, applying a resinous composition composed of phenol-aldehyde, an oil-modified alkyd resin and a hydrolyzed polyvinyl ester in a liquid medium, and heat-treating the conductor to remove the liquid medium and to cure the applied materials to produce an insulated conductor.

8. In the method of applying glass fibers in the form of sliver in combination with a resinous binder and impregnant for the interstices between glass fibers to an electrical conductor to provide for electrically insulating the conductor comprising, applying a sliver of glass fibers to the electrical conductor, applying a hydrolyzed polyvinyl ester in a liquid carrier to the applied sliver, heat-treating the conductor to remove the liquid carrier, applying a resinous composition composed of phenol-aldehyde, an oil modified alkyd resin and a hydrolyzed polyvinyl ester in a liquid medium, and heat-treating the conductor to remove the liquid medium and to cure the applied material, applying a coating of hydrolyzed polyvinyl ester in a liquid carrier to the conductor and heat-treating the conductor to remove the solvent and to render the applied coating adherent to the glass fibers to produce a smooth-surfaced insulated conductor.

9. The method of applying glass fibers in the form of sliver in combination with a resinous binder and impregnant for the interstices between glass fibers to an electrical conductor to provide for electrically insulating the conductor comprising, applying to the electrical conductor a resinous binder capable of adhering to glass fibers, applying a sliver of glass fibers to the electrical conductor, applying a first coating of a resinous composition composed of phenol-aldehyde, an oil-modified alkyd resin and a hydrolyzed polyvinyl ester, heat-treating the coating, applying a hydrolyzed polyvinyl ester in a liquid carrier to the applied sliver, heat-treating the conductor to remove the liquid carrier, applying a second coating of resinous composition composed of phenol-aldehyde, an oil-modified alkyd resin and a hydrolyzed polyvinyl ester in a liquid medium, and heat-treating the conductor to remove the liquid medium and to cure the applied material, applying a coating of hydrolyzed poly-

vinyl ester in a liquid carrier to the conductor and heat-treating the conductor to remove the solvent and to render the applied coating adherent to the glass fibers to produce a smooth-surfaced insulated conductor.

10. The method of applying glass fibers in the form of sliver in combination with a resinous binder and impregnant for the interstices between glass fibers to an electrical conductor to provide for electrically insulating the conductor comprising, applying a sliver of glass fibers to the electrical conductor, applying a resinous composition composed of phenol-aldehyde, an oil-modified alkyd resin and a hydrolyzed polyvinyl ester in a liquid medium, and heat-treating the conductor to remove the liquid medium and to cure the applied material, applying a coating of a hydrolyzed polyvinyl ester in a liquid carrier to the conductor and heat-treating the conductor to remove the solvent and to render the applied coating adherent to the glass fibers to produce a smooth-surfaced insulated conductor.

11. An insulated conductor comprising, in combination, an electrical conductor, glass fibers selected from the class consisting of sliver and staple yarn applied to the conductor, and a resinous composition applied to the electrical conductor and heat treated to bind the glass sliver thereto, the composition impregnating the interstices between the glass fibers to provide for a smooth exterior surface free from projecting glass fibers and to provide for good electrical insulation, the resinous composition composed of an oil-modified alkyd resin, phenol-formaldehyde and hydrolyzed polyvinyl ester.

12. An insulated conductor comprising, in combination, an electrical conductor, glass fibers se-

lected from the class consisting of sliver and staple yarn applied to the conductor, and a resinous composition applied to the electrical conductor and heat treated to closely bind the glass fibres thereto, the composition impregnating the interstices between the glass fibers to provide for a smooth exterior surface free from projecting glass fibers and to provide for good electrical insulation, the resinous composition applied as a plurality of coatings, including an initial coating upon the conductor composed of from 10 to 25 parts of phenol-formaldehyde combined with from 25 to 100 parts of an oil-modified alkyd resin, subsequent coatings applied to the sliver composed of from 10 to 25 parts of phenol-formaldehyde combined with from 25 to 100 parts of an oil-modified alkyd resin and 2 to 20 parts of hydrolyzed polyvinyl ester and coatings of the hydrolyzed polyvinyl ester alone.

13. An insulated conductor comprising, in combination, a conducting member, glass fibers in the form of sliver or yarn applied to the conducting member, and a resinous composition applied to bond the glass sliver to the conducting member, the resinous composition impregnating the interstices between the fibers of the glass sliver to provide a smooth exterior surface free from projecting ends of glass fibers and good electrical insulation, the resinous composition applied as a plurality of coatings, including at least one coating composed of phenol-formaldehyde combined with an oil-modified alkyd resin, and at least one coating of a hydrolyzed polyvinyl ester applied to the glass fibers whereby the glass fibers are drawn in and closely bound to the conductor.

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