

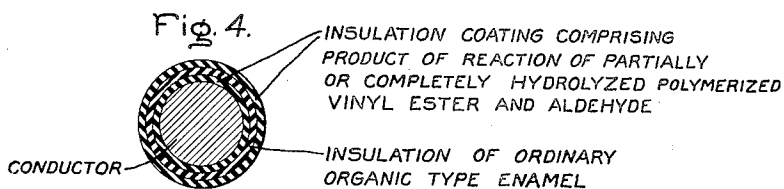
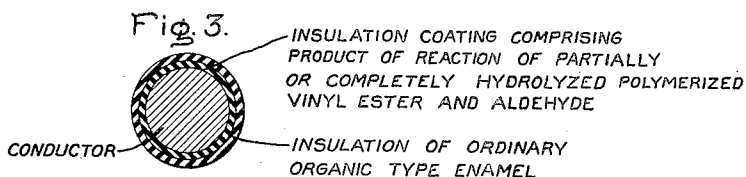
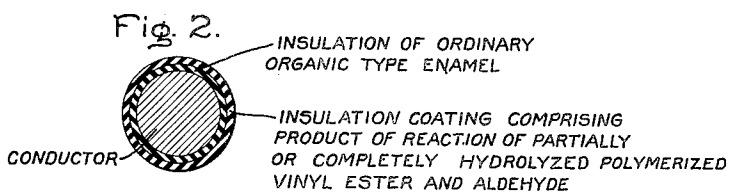
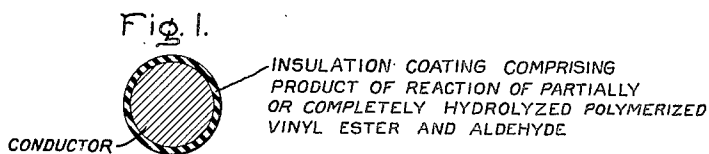
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INSULATED ELECTRICAL CONDUCTOR AND PROCESS OF MAKING SAME

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INSULATED ELECTRICAL CONDUCTOR AND
PROCESS OF MAKING SAMEWinton I. Patnode and Edward J. Flynn, Sche-
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9 Claims. (Cl. 173—264)

Our invention is concerned with insulated electrical conductors and the process of making the same. It is more particularly concerned with the manufacture of insulated electrical conductors having insulation of the organic enamel type thereon.

In the manufacture of insulated electrical conductors wherein the insulation is of the organic enamel type an electrical conductor, for example copper wire, is usually first run through a bath of enamel, such as drying oil enamel. On leaving the bath the conductor carrying the enamel is run through a baking oven or tower where the enamel is baked. Usually it is necessary to run the same wire successively through the enamel bath and baking oven several times in order to provide adequate insulation thereon.

In the manufacture of large types of electrical apparatus, such as large motors where random wound coils are used, the enamelled wire is wound either directly on the core or other member of the apparatus for which it is intended, or the wire is separately formed as a coil and then assembled in the machine. However it may be fabricated the entire structure is impregnated with an insulating varnish and baked at a temperature as high as 150° C.

In order to be satisfactory for use as an insulation on wire, an enamel film must have the property of hardness, which imparts resistance to abrading action encountered in the assembly of the machine. It also must have resistance to the softening action of solvents encountered in the subsequent varnish treatment. The film must also have good adhesion to the base metal and considerable extensibility without cracking or peeling from the wire. These last two properties permit of the necessary stretching of the wire on winding and allow the film to stand up unimpaired under the heat shock encountered on being placed in a baking oven.

The conventional oil type enamels as used in practice make it necessary to effect a compromise between these properties in order to obtain a satisfactory insulation. Such a compromise is illustrated by the following tests which are made to determine whether or not enamelled wire is satisfactory for use in motors. The property of extensibility is determined by taking, for example, an enameled wire and elongating it 10% and winding it after elongation on a mandrel three times its own diameter. If the enamel does not crack, the insulated wire is considered satisfactory from the standpoint that it can be successfully wound into coils. The property of hard-

ness is determined, for example, by elongating an enameled wire 20% and winding it as above indicated. Under these conditions the enamel on the wire must crack to show that it has been baked sufficiently to withstand abrasion and solvent attack during varnish treatment such as described in the foregoing paragraph.

Since the hardness, abrasion resistance, and resistance to softening by varnishes are improved by increased baking of the enamel, and since the flexibility and extensibility of the film are impaired by increased baking, then the above test illustrates the sort of compromise that is practiced in order to manufacture conventional enamelled wire. Furthermore, when conventional enamelled wire is stretched, as is done in many winding operations, and is then subsequently baked in the apparatus during the varnish treatment, it is prone to crack owing to the heat shock, especially when the film has been baked hard to make it abrasion-resistant. In many places in the manufacture of electrical apparatus it is necessary to cover the enamelled wire with cotton or paper to protect the film from damage during the mechanical winding operations, and to provide a medium for the impregnating varnish to fill in order to cover up such damage, when it occurs. Such use of cotton or paper is wasteful of space and material. Our invention provides an insulated wire of the enamel type which is not subject to the harmful effects noted above, which does not have to be manufactured on a basis of compromise of one property in order to get another, and which, by virtue of possessing all of the desirable properties enumerated above, does not require the additional covering of cotton or paper.

In accordance with our invention we utilize a class of organic materials derived from vinyl bodies as more fully described below, which we have found not only fulfils the above requirements of hardness and extensibility but produces, in addition, an insulated electrical conductor on which the insulation is very adherent, tough and flexible, remarkably abrasion-resistant, of high dielectric strength, low power factor and resistant to attack by such agencies as oil and the like.

The accompanying drawing illustrates diagrammatically the invention. In this drawing Fig. 1 is a cross sectional view of an electrical conductor provided with insulation in accordance with our invention; Fig. 2 is also a cross-sectional view showing the conductor provided with a coating of insulation of ordinary organic type enamel and a superposed coating of the insula-

tion of the special organic material hereinafter described; Fig. 3 is another cross sectional view illustrating a further modification of the invention; and Fig. 4 is also a cross sectional view showing a still further modification of the invention.

The class of organic materials which we have discovered to be particularly adapted for the production of insulated electrical conductors in accordance with our invention is the class of compounds produced, generally speaking, by reacting a partially or completely hydrolyzed polymerized vinyl ester with an aldehyde. The preparation of such compounds is set forth for example in British Patent No. 351,082 of 1931. As a specific example of a procedure which we at present prefer for preparing such a compound we give the following:

100 parts of a polymerized vinyl acetate is dissolved in 185 parts of glacial acetic acid. To this is added 83 parts of Formalin solution and 6.8 parts of concentrated sulphuric acid. Hydrolysis is carried out at 70° C. in an enamelled vessel fitted with an agitator for a period of 20 to 25 hours. A test sample taken about the sixteenth to eighteenth hour will indicate the exact time for the hydrolysis. 13 parts of ammonia solution are added for neutralization and the reaction mixture is precipitated as threads in water, washed and dried in a current of warm air (about 60° C.).

According to our invention the thread-like material is dissolved in a suitable solvent such for example as dioxan, ethylene dichloride, chloroform, furfural or a mixture of solvents as, for instance, 85% monochlorobenzene and 15% ethyl alcohol. Various concentrations of solution can be made and the material will dissolve in the solvents either at room or elevated temperatures.

The solution is employed as a wire enamel for coating wire. For example, a 6 to 8% solution in dioxan has been employed and applied to wire with usual wire enamelling apparatus employing a suitable wiper and baking the coating on the wire in an electrically heated oven. A 0.00025" film on fine copper wire showed a dielectric strength of from 1000 to 1350 volts per mil. Although there was but one coating on the wire, which, as will be observed was very thin, the continuity of the insulating film was nearly perfect, a length of 66 feet showing no breaks and having an insulation resistance of at least 50,000 ohms per inch at all points along its length. It is well known that it is practically impossible to produce wire having a continuous insulating film in one coat when ordinary organic enamels at present in vogue are used and utmost care is taken to carefully clean the wire before application of the enamel.

In addition to producing excellent insulated wire with but a single coat of insulation, using a 10% dioxan solution of the material, two coats produced a film 0.00045" in thickness of excellent continuity and having an average dielectric strength of 1100 volts per mil.; four coats produced a film 0.0013" in thickness with a dielectric strength of 1270 to 1680 volts per mil.

It is also possible to provide heavy films of the vinyl insulation on conductors. This may be done from solution as in the case of the production of thin films or by the strip covering method, that is, by employing a sheet or tape of the insulation and applying it to the conductor according to well known strip covering methods. For example, 0.0385" copper wire has been coated from a solution consisting of 85% chlorobenzene

and 15% ethyl alcohol with an insulation 1.25 to 1.5 mils thick which gave average breakdown of 2.06 kv. between the conductor and mercury in which the coil of wire was immersed for test.

The insulation film on the wire is extremely tough and flexible. When the wire was stretched until it broke, the insulation showed no cracks except at the point of break. Wire covered with this insulation exhibits astounding resistance to abrasion, distortion, bending and hammering. For example, wire insulated in accordance with our invention can be elongated to the breaking point of the wire and wound on itself as a mandrel without cracking the film. The insulated wire can be elongated to any extent necessary in practical manufacturing treated with varnish and immediately placed in an oven at a temperature of 150° C. without cracking or impairing the film. The insulated wire can be hit with a hammer on a steel anvil to such an extent that the diameter of the wire is decreased by at least 50% without breaking the film.

Under no circumstances is the insulation film attacked by the varnish solvents generally used at the present time in treating electrical apparatus, i. e., solvents derived from coal tar and petroleum. The insulated wire can be soaked in toluol for 48 hours without impairing the usefulness of the film. Films from ordinary organic enamels under such drastic action swell and peel off.

Two pieces of wire insulated in accordance with our discovery can be wound on themselves and then can be deformed in an ordinary jaw vise so that the cross-hatching of the vise is very apparent in the film and the insulation resistance between the two wires is still of the order of 10¹³ ohms or higher indicating that the insulation has been unimpaired by this treatment.

The abrasion resistance of our insulated wire is one of its outstanding properties from a practical standpoint. On test equipment it consistently runs four times as good as the best commercial double enamelled wire with which it is compared. From the standpoint of abrasion, our insulated wire is superior to an ordinary enamelled wire covered with cotton or paper. Hence wires can be insulated with the films of the material only and no covering of cotton or paper is required to protect the film from mechanical damage.

The dielectric strength of the films produced is high and the dielectric losses are low. It is therefore possible to use a much thinner overall insulation than hitherto employed. Because less insulation is required, more copper can be placed in the slot of a motor or generator resulting in an increased rating of the machine. This applies to transformers, regulators and other electrical apparatus in which insulated wire is used in the form of a coil. Conversely, if the rating of the machine is kept constant, savings in copper and iron result.

Advantage may be taken of the exceptional toughness of the insulation films in reinforcing regular enamelled wire against abrasion. In this case a coat of the insulation is applied on top of the regular enamel as shown in Fig. 2. This outer coat is advantageous in another connection. It does not readily oxidize and become brittle when heated for long periods of time. Ordinary enamels made from drying oils become brittle upon baking, presumably due to continued oxidation. A coat of the insulation made in accordance with our invention aids materially in

preventing this embrittlement. Also, by providing a conductor with an initial coat of the insulation described, the adherence of ordinary organic enamels subsequently placed thereon is improved. If desired therefore, a conductor may be first provided with a coating of the vinyl compound in accordance with our invention, then one or more coatings of ordinary types of organic enamel may be applied as shown in Fig. 3, after which, if desired, an outer coating or coatings of the vinyl compound may be provided thereon as shown in Fig. 4.

It is of course understood that where we refer to ordinary organic enamels it is not limited to the drying oil types of enamels but includes all classes of ordinary organic enamels examples of which are well known.

What we claim as new and desire to secure by Letters Patent in the United States is:

1. An electrical conductor insulated with an organic insulation comprising the product of reaction of formaldehyde and hydrolyzed polymerized vinyl acetate, said product being heat-treated to produce a hard, flexible, tough abrasion-resistant insulation.

2. An electrical conductor insulated with an organic insulation comprising the product of reaction of an aldehyde and hydrolyzed polymerized vinyl ester, said product being heat-treated to produce a hard, flexible, tough, abrasion-resistant insulation.

3. An electrical cable comprising an electrical conductor and high dielectric strength insulation therefor, said insulation comprising a coating of organic enamel next to said conductor and a superposed coating of organic compound comprising the heat-treated product of reaction of an aldehyde with hydrolyzed polymerized vinyl ester, said superposed coating being in a hard, flexible, tough, abrasion-resistant state.

4. An electrical conductor insulated with multiple layer insulation comprising an inner coating of organic compound comprising the heat-

treated product of reaction of an aldehyde with hydrolyzed polymerized vinyl ester, said inner coating being directly on said conductor, a coating of organic enamel on said inner coating, and an outer coating of organic compound comprising the heat-treated product of reaction of an aldehyde with hydrolyzed polymerized vinyl ester, said outer coating being hard, flexible, tough and abrasion-resistant.

5. An electrical conductor provided with a hard and flexible coating of an organic compound comprising the heat-treated product of reaction of an aldehyde with hydrolyzed polymerized vinyl ester and a superposed coating of organic enamel.

6. An electrical conductor provided with a hard, flexible, tough, abrasion-resistant coating of high dielectric strength, said coating being the heat-treated product of reaction of an aldehyde and hydrolyzed polymerized vinyl acetate.

7. The method of insulating a conductor which comprises coating the conductor with a solution of an organic compound comprising the product of reaction of an aldehyde with a hydrolyzed polymerized vinyl ester and baking said conductor with the coating to a hard, flexible, tough, abrasion-resistant state.

8. The method of improving the adherence of organic enamels to electrical conductors which comprises coating the conductor with a solution of an organic compound comprising the product of reaction of an aldehyde with a hydrolyzed polymerized vinyl ester, baking the coated conductor, coating the latter with an organic enamel and again baking the coated conductor.

9. An electrical conductor insulated with an organic insulation comprising the product of reaction of formaldehyde and hydrolyzed polymerized vinyl ester, said product being heat-treated to produce a hard, flexible, tough abrasion-resistant insulation.

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