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N. C. FOSTER ET AL

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INSULATION FOR ELECTRICAL APPARATUS

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Fig. 1.

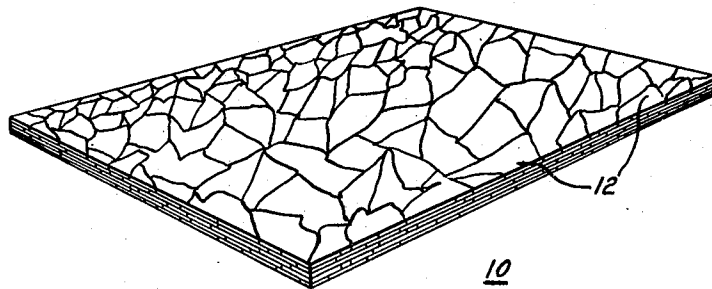


Fig. 2.

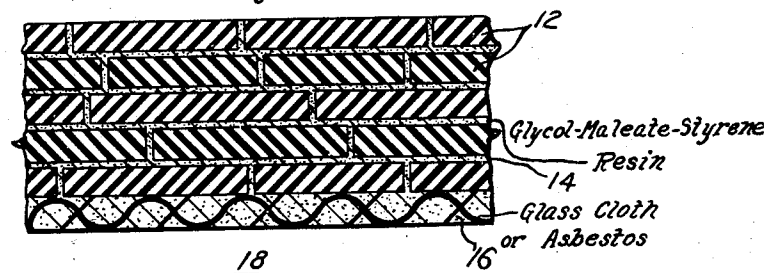
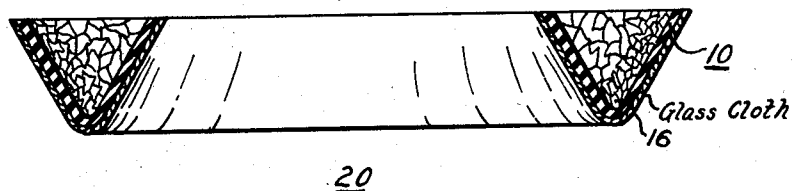


Fig. 3.



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INSULATION FOR ELECTRICAL APPARATUS

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1 Claim. (Cl. 154—2.6)

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This invention relates to electrical insulation comprising mica flakes and a thermosetting binder.

In certain applications of electrically insulating substances, the requirements call for not only good dielectric strength, but high physical properties, resistance to high temperatures, and high arc resistance. This combination of properties is indispensable, for example, in commutator and slip-ring insulation and similar service. For this service it has been customary to prepare insulation from mica flakes with a binder giving a body or sheet material that meets the requirements satisfactorily.

Owing to the nature of mica flakes, only a limited number of binders or adhesives are known to those skilled in the art having the peculiar property of wetting mica and effectively bonding mica flakes to produce a high-grade insulating body. Shellac is commonly employed as a binder for mica flakes despite some disadvantages because it has the best overall combination of properties and has been inexpensive in price. At the present time, shellac is not available to the extent required for the electrical industry and it has been necessary to find a mica binder that will meet the important requirements of electrical insulation as well as shellac does.

Important among the requirements for service as commutator insulation is high arc resistance, since due to the sparking occurring at the commutator, low arc resistant materials will break down rapidly and soon fail permanently. For efficient operation commutators must be maintained in a predetermined position in spite of high operating stresses which may result both from the method of attaching the commutators to the apparatus and from the expansion of the commutator segments due to high temperatures during operation. To meet these requirements commutator insulation should be characterized by a set of less than 10% at pressures of 1,000 pounds per square inch at 150° C. In many cases, commutator insulation is subjected to oils and greases and, therefore, chemical stability and resistance to these substances is required. Dielectric resistance is a valuable property though not as critical as the foregoing criteria since in most cases the voltage between adjacent commutator segments is relatively low.

To facilitate application to commutators, solid insulation must be moldable with relatively sharp corners, as in the form of V-rings, without cracking or failure at such sharp corners. Ease of punching or shaping is required since the solid

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insulation should be easily and accurately shaped for use as intersegmental insulation. Resistance to temperatures of the order of 120–150° C., or even higher, is needed since commutators will frequently approach these temperatures, particularly in heavy service.

According to this invention, it has been discovered that mica flakes are wetted and exceptionally well bonded by a synthetic organic resin produced by reacting styrene, or a simple methyl substituted styrene, with the ester of an alpha-beta unsaturated dicarboxylic acid, such as maleic anhydride, and a glycol. Other desirable properties of this binder are its high dielectric strength and an arc resistance of the order of 185 seconds (ASTM). Additional desirable and valuable characteristics of this resin when applied to mica flakes will be disclosed hereinafter.

The object of this invention is to provide electrical insulation composed of mica flakes and a thermosetting synthetic resin binder.

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 this invention, reference should be had to the following figures of the drawing, in which:

Figure 1 is a perspective view of a sheet of bonded mica insulation produced in accordance with the teaching of this invention;

Fig. 2 is a greatly enlarged fragmentary cross section of a modified form of the invention of Fig. 1; and

Fig. 3 is a view in elevation partly in section of a V-ring embodying the structure of Fig. 2.

The synthetic organic resin which is applied to mica flakes in practicing this invention is the reaction product of styrene or a simple methyl substituted styrene, such as paramethyl alpha-methyl styrene, with the ester of maleic anhydride and a glycol. To provide for the best electrical and mechanical properties, it has been discovered that the ester must be produced within closely maintained limits. One mol of maleic anhydride must be esterified with one mol within +2% or -2% of a glycol, such as propylene glycol. The ester produced within these limits has an arc resistance of 185 seconds, whereas a product employing an ester in which the departure from molar equality is 4% may have an arc resistance of 135 seconds or less. Other electrical and mechanical properties may be adversely affected when the ester is produced outside of the specified limits.

The esterification reaction of maleic anhy-

dride and propylene glycol, for example, is carried out in an enclosed reaction vessel embodying a stirrer and a condensing column. The reaction vessel is maintained at a temperature of about 230° C. in order to cause a rapid esterification of the propylene glycol and the maleic anhydride. While temperatures of about 200° C. may be employed, the time of reaction will be longer. In some cases, catalysts such as para toluol sulphonic acid may be introduced into the reaction vessel, but a catalyst is not necessary. A non-reactive gas, for example, nitrogen, at a pressure of about 1 pound above atmospheric, is continually bubbled through the reactants. The water evolved during the esterification is removed from the reactants by the inert gas, condensed in the column attached to the vessel and then may be removed from the vessel.

In a period of time from 8 to 16 hours, the acid number of the ester will have reached a value of from 20 to 90. For the purpose of this invention, an acid number of around 70 is quite desirable since the resin will then be of a suitable toughness without being too hard. An ester having an acid number of around 50 will be found to produce a final resin which is quite hard, while an ester with an acid number of 80 gives a relatively soft product which may be desirable for some purposes. A good test for determining whether the reaction is complete for the practice of the invention is to test a sample of the ester by a ball and ring test—resins having a ball and ring of 60° to 70° C. being satisfactory. However slightly higher or lower ball and ring numbers may be indicative of a suitable product for some purposes. The ester, when at the desired acid number and ball and ring temperature, is dumped from the reaction vessel while hot into a pan or tank where it is allowed to cool to room temperature or slightly higher.

After being cooled, the glycol-maleate ester is dissolved by adding a suitable solvent therefor, such, for example, as benzene, acetone, methyl-ethyl ketone, or higher ketones or mixtures thereof. In practicing this invention, it has been found that exceptionally good results have been obtained with a solvent mixture consisting of approximately 50% benzene and 50% acetone. For some unexpected reason, the acetone-benzene mixture is capable of producing a resin solution that will penetrate fibrous material and spread between mica flakes by capillary action at a rate that is estimated at about 100 times that of a solution of the resin in acetone alone having the same viscosity. The satisfactory penetration of material to which the solution may be applied at a high rate results in a saving of time as well as producing a better product.

To the ester solution so prepared about 0.1% to 1% of an inhibitor, such for example as hydroquinone, eugenol, or quinhydrone, or, in some cases, organic copper salt inhibitors, may be added, in order to increase the storage life at room temperature as well as to secure a predetermined rate of solidification of the resin during subsequent operations, including the final molding heat treatment of the insulation produced therewith.

After adding the inhibitor, 20% to 50% by weight of monostyrene, or a simple substituted styrene, such as monomeric alpha methyl para methyl styrene, based on the weight of the glycol-maleate ester is added to the solution. The proportions of the styrene determine the relative hardness of the final product. Compositions having about 20% monostyrene and 50% mono-

styrene, respectively, are relatively soft, while those embodying an intermediate amount of from 25 to 40% of monostyrene are much harder and in most cases, somewhat more desirable for the practice of the invention.

Just prior to applying the solution to mica flakes and the like from about 0.5% to 2% of a catalyst, such as benzoyl peroxide, ascaridole, or other organic oxide or other suitable catalyst is added to the solution of resins. The ratio of catalyst to inhibitor determines the tank life, the rate of setup of the resin, and the time and temperature required in the final heat-treatment of the insulation. A ratio of 1 part of inhibitor to from 4 to 30 parts of catalyst has given excellent results.

For application to mica flakes, a 27% solids solution in a 50% acetone-50% benzene solvent mixture proved to be quite satisfactory. The resin solids in the solution were composed of approximately 4 parts by weight of the glycol-maleate and one part of styrene. In the solution 0.1% quinhydrone, as an inhibitor, and 2% benzoyl peroxide, as a catalyst, was present.

This specific solution was employed in a commercial wet bond mica machine where it was applied to a layer of mica flakes by dripping on the mica flakes passing below on a moving belt. The mica flakes with the solution were then subjected to heating in an oven to remove the major portion of the solvent. The resins penetrated between the mica flakes with good wetting and adhesion, giving a long flexible sheet. The flexible sheet was cut into standard sized shapes, and the cut pieces superimposed to produce a predetermined thickness. The stack of cut pieces was then subjected to heat and pressure of the order of 200 pounds per square inch at a temperature of 160° C. for 1½ hours. The product was a hard thermoset sheet or body of the type shown in Fig. 1 of the drawing. The sheet 10 is sanded in a drum sander to a substantially uniform thickness. The sheet 10 may be milled, cut, or punched to produce any predetermined shape or form of electrical insulator required. In order to provide for predetermined strength and other properties, a modification of the structure shown in Fig. 1 may be prepared by disposing the flexible partially dried sheets from the mica machine upon a layer of a reinforcing fibrous fabric, such as glass cloth or asbestos cloth. Sufficient of the solution of the glycol-maleate-styrene resin may be applied to the cloth to impregnate the interstices of the fibers, the impregnated cloth being dried to remove the solvent. Upon being subjected to heat and pressure, a unitary body, such as shown at 18 in Fig. 2, will be produced. The mica flakes 12 and the glass or asbestos cloth 16 will be bonded into a unitary thermoset body.

Where it is desired to produce electrical insulation having predetermined curvature or a shape other than a flat sheet, the flexible mica sheets produced from a mica machine may be superimposed to a predetermined thickness and pressed at several hundred pounds per square inch at about 150° C. for a short period of time of the order of a minute. The resin will not have completely hardened under this treatment and is sufficiently flexible or plastic to withstand molding and shaping to any desired form. However, the resin is hard enough to sand to predetermined thickness without gumming, delaminating, or breaking up the partially hardened sheet. The sheet may then be cut by means of a saw or

punched in a press to a selected shape, for example, a ring or a collar for pressing into a V-ring. The cut or punched members may be finish molded by subjecting them to pressure in a shaped die at a higher pressure at a temperature of the order of 150° C. for one-half hour or more. V-rings, channels, tubes, and other forms of mica insulation may be produced by this procedure.

In some cases it may be advantageous to employ the reinforced mica sheet of Fig. 2 in producing V-rings. A structure of this kind is shown at 20 in Fig. 3 where the glass cloth 16 has been applied to the sheets of mica flakes and the whole molded to a V-ring shape with the glass cloth 16 disposed at the outer side of the V. In other cases, reinforcing glass or asbestos may be disposed within the V as well.

The amount of resin in the bonded sheet of mica flakes may range from 3% to 10% or more, depending on the physical requirements, the size of the mica flakes, and other factors.

It will be apparent to those skilled in the art that the styrene-glycol-maleate resin may be heat-treated at higher pressures of up to 1 ton per square inch or more, and at lower or higher temperatures than 150° C., suitable provision being made by extending or shortening the period during which the pressure and temperature are applied. The resin produces a thermoset product that will not soften or distort even when operated continuously at 200° C. for prolonged periods of time.

Among the properties of the binder that render it advantageous for bonding mica flakes to produce high grade electrical insulation are its complete insolubility in any known solvent when completely polymerized to a thermoset state. It is oil and water-proof as well. Most acids and alkalis appear to have very little effect upon the resin. The temperature stability is exceptionally good; one inch cubes of the resin having been maintained at 200° C. for one month with a loss of less than 1% by weight. The arcing resistance of mica flake insulation prepared therewith is 185 seconds and higher, and the resin is not subjected to tracking when exposed to arcs. The dielectric strength is better than 500 volts per mill for one-eighth inch thick sheet.

The physical properties of mica flakes bonded with the resin binder of this invention are outstanding. The tensile strength is over 20,000 pounds per square inch. No evidence of cold flow or hot distortion is evident over a wide range of conditions. Tests indicate that the bond strength between the resin and mica is superior to that of shellac. V-rings produced according to this invention have been subjected to compression pressures of over 10,000 pounds per square inch

at 175° C. without slip or distortion taking place.

Many glycols, such, for example, as diethylene glycol, ethylene glycol, butylene glycol, or polyethylene glycols may be employed in producing a suitable ester. Mixtures of glycols are contemplated in the practice of the invention. In all cases, equimolar amounts of glycol per mol of maleic anhydride should be maintained within 2%. Maleic anhydride has been found to give excellent results in the practice of this invention. In some cases, maleic acid, fumaric acid, citraconic acid or citraconic anhydride may be employed alone or admixed with maleic anhydride with good results.

Since certain obvious changes may be made in the above procedure and different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

We claim as our invention:

The process of preparing mica insulation which comprises applying to mica flakes a solution composed of 100 parts by weight of the ester of substantially equimolar amounts of at least one unsaturated compound selected from the group consisting of maleic anhydride, fumaric acid, citraconic acid, citraconic anhydride and maleic acid, and a glycol and from 20 to 50 parts by weight of monostyrene and a volatile organic solvent comprising essentially benzene and acetone, heating the treated mica flakes to remove the volatile organic solvent and applying heat and pressure to the mica flakes to copolymerize the glycol maleate ester and monostyrene into a thermoset binder for the mica flakes.

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