

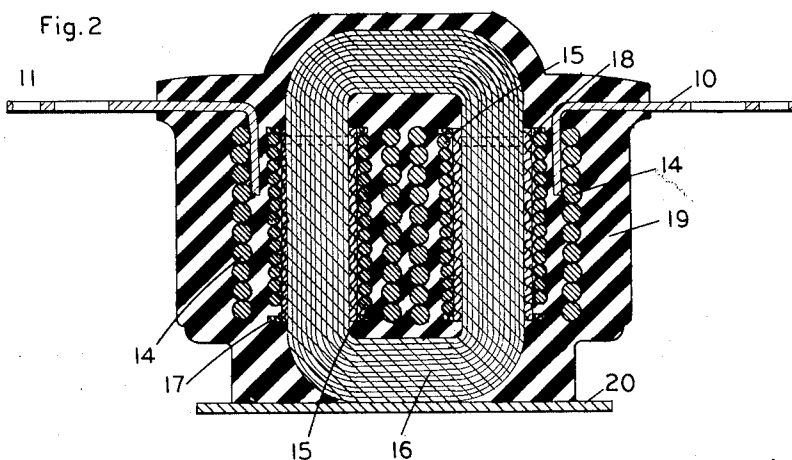
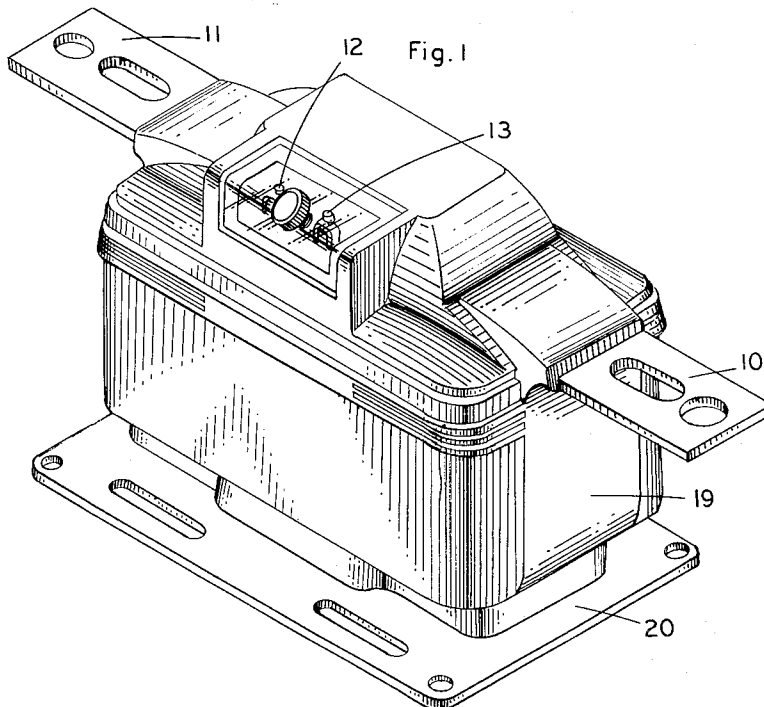
Aug. 22, 1961

A. A. KESSEL ET AL
ELECTRICAL APPARATUS HAVING INSULATION
FOR ELIMINATING CREEPAGE TRACKING

2,997,527

Original Filed Jan. 9, 1957

2 Sheets-Sheet 1



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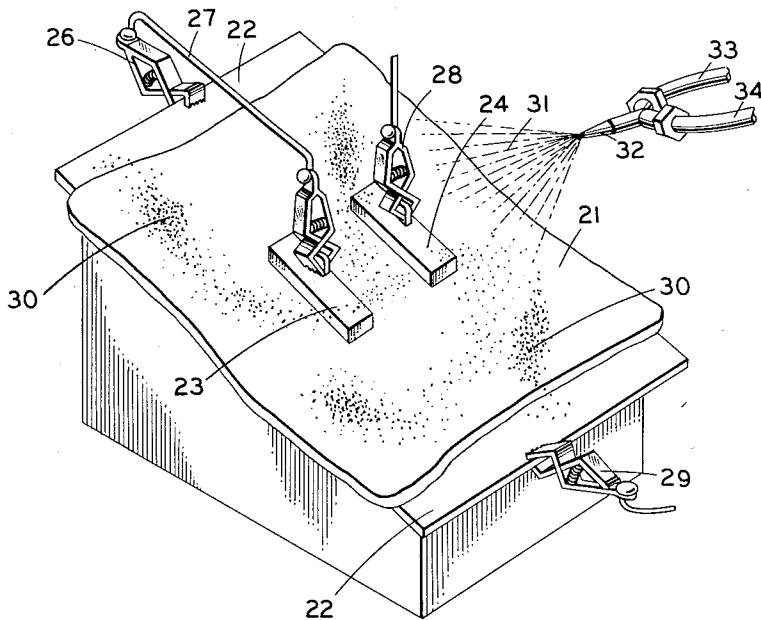


Fig. 3

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ELECTRICAL APPARATUS HAVING INSULATION FOR ELIMINATING CREEPAGE TRACKING

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Original application Jan. 9, 1957, Ser. No. 633,356.

Divided and this application Feb. 14, 1958, Ser. No. 715,408

6 Claims. (Cl. 174—137)

The present invention relates to improvements in the insulation of electrical apparatus and, more particularly, to electrical devices and improved insulations therefor which are subject to contaminated conditions which promote creepage electrical discharge conditions. As is well known, certain types of electrical equipment subjected to contaminating atmospheric conditions such as moisture, dust, fog and salt frequently fail due to creepage between points of different potentials on the equipment. While the insulating components of electrical equipment desirably include organic materials which are inexpensive and readily molded or otherwise fabricated, it has been a particular disadvantage that the organic constituents of such components tend to form carbonaceous deposits upon exposure to conditions which promote such creepage. These carbonaceous deposits ultimately provide paths of sufficiently low resistance to occasion breakdown of the equipment. This application is a division of our copending application, Serial No. 633,356, filed January 9, 1957, which latter application in turn is a continuation in-part of our copending application, Serial No. 523,445, filed July 21, 1955, now abandoned.

By way of example, in the instrument transformer field, it has heretofore been a distinct limitation to the usefulness of "dry" molded instrument transformers that the molded organic insulation components thereof form low-resistance carbonaceous deposits upon exposure to creepage electrical discharges. High-voltage transformers of this "dry" type may include molded organic insulating compounds not only as the insulation between elements but as the outer protective casing as well, and are thus distinguished from those which are filled with oil or other insulating liquids. In outdoor installations, or others where there may be accumulations of dust, rain and other environmental contaminants, random surface discharges or arcing known as "surface creepage" are promoted between elements. These discharge conditions occasion the formation of carbonaceous deposits in the insulation, ultimately yielding low-resistance paths or tracks which destroy further utility of the apparatus. Discharges of the creepage type are to be distinguished from those caused by the establishment of an arc through or directly between two parts of the apparatus having different potentials. Under arcing conditions, while the organic material adjacent to the arc is carbonized, the arc track so formed is not random in character but forms a direct path along the line of the arc. On the other hand, tracks due to creepage are random in effect and produce a tree-like path. The difference between tracking due to arcing and tracking due to creepage is further pointed out in ASTM Test D495-48T in which it is stated specifically that the test directed to determining the resistance of insulating material to arcs does not in general permit conclusions to be drawn as to the resistance of the material to other types of arc such as those promoted by conducting contaminants with which latter the present invention is concerned. It is further pointed out that in the creepage type of electrical failure, failure of the material can occur not only due to surface failure but to subsurface failure. In other words, even if the surface of the organic material is devoid of carbonaceous or conducting material, track-

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ing due to surface creepage may nevertheless occur between two points of different potential beneath the surface of the material itself. It is evident from the above and it has been found that materials which are effective in protecting against the effects of direct arcing are not necessarily effective in protecting against creepage breakdown.

As a result of such disadvantages, organic insulating components have been avoided in the construction of electrical equipment wherein such components would be subjected to the influences of creepage electrical discharges, even though these components would otherwise have been attractive because of different considerations. Organic insulating materials which experience this limitation include epoxy resins.

Accordingly, it is one object of this invention to provide improved electrical apparatus having epoxy resin organic insulation which eliminates tracking due to creepage electrical discharge conditions.

It is another object to provide improved electrical apparatus including epoxy resin organic compositions which have insulating characteristics and in which formation of carbonaceous deposits upon exposure to creepage type electrical discharges is eliminated.

By way of a summary account of one practice of the teachings of this invention, an improved high-voltage outdoor instrument transformer includes a magnetic core member with linked primary and secondary windings each connected to terminals, and an epoxy resin organic composition having hydrated alumina dispersed therein in proportions defined hereinafter. The epoxy resin composition with the hydrated alumina is formed about the transformer elements to electrically insulate them and to provide an outer covering which protects these elements against influences of the ambient environment. Uniquely, the creepage discharges occurring across the surface of the transformer even under the most severe contaminating conditions do not occasion tracking and breakdown, inasmuch as low-resistance carbonaceous deposits are not permitted to form.

Although the features of this invention which are novel are set forth in the appended claims, greater detail of the invention in its preferred embodiments and the further objects and advantages thereof may be readily comprehended through reference to the following description taken in connection with the accompanying drawings, wherein:

FIGURE 1 provides a perspective view of a typical molded casing type transformer embodying our invention;

FIGURE 2 is a cross-sectional view of the transformer of FIGURE 1; and

FIGURE 3 is a pictorial view of electrical test equipment utilized to procure operating life data.

Referring to FIGURES 1 and 2 of the drawings, the electrical apparatus there shown is a current transformer having primary terminals 10 and 11 and secondary terminals 12 and 13. The positioning of the primary windings 14 and the secondary windings 15 will be apparent from the view of FIGURE 2. These windings are electromagnetically linked with a core 16 of magnetic material which is provided with a pair of tubular separators 17 and 18 which serve to insulate the core from the windings.

The transformer of FIGURES 1 and 2 includes composition 19 which encapsulates the various components as shown and thereby provides a completed physical enclosure as well as electrical insulation. A support plate 20 facilitates mounting. As has been pointed out above, organic insulating materials heretofore employed as such components of transformers of this type, and in other applications wherein similar conditions may occur, have been subject to the basic problem of carbonaceous resi-

due formation and accumulation occasioned by random electrical creepage discharges which are likely to occur under adverse climatic conditions in outdoor installations. This difficulty is attributable to the inherent characteristics or organic materials of this type which cause them to break down to form low-resistance carbonaceous deposits when exposed to creepage type electrical discharges. Composition 19 includes epoxy resin and hydrated alumina dispersed therein in sufficient quantity to prevent accumulation of carbonaceous deposits upon exposure to creepage electrical discharges such as those which may occur between the conducting members 10, 11, 12, 13 and 20.

With apparatus not embodying our teachings, it is believed that the breakdown process with respect to creepage failures occurs as follows. The localized high-temperature discharges produced across the surface of the epoxy resin breaks down the epoxy resin components to form carbon deposits. The process is cumulative, as has been previously described, and low-resistance tracking failure occurs rapidly.

Electrical apparatus wherein exposure to contaminating conditions is likely to occur and in which our teachings may be embodied to great advantage include also apparatus other than current transformers which are unprotected from such contaminating conditions. In accordance with one practice of our invention, we provide high-voltage electrical apparatus in which conductors having a large potential difference are found with an epoxy resin insulating material having interspersed therein a hydrated alumina in proportions such that material breakdowns ordinarily experienced under creepage electrical discharge conditions do not occur. The concentration of the hydrated alumina employed is critical since it has been found that only a sufficient concentration eliminates carbon accumulation and electrical breakdown. As will be demonstrated, this effect can be achieved by employing a hydrated alumina only in the hereinafter defined critical proportions. A very marked increase in operating life of the apparatus under creepage electrical discharge conditions is observed as the critical levels of concentration are reached.

Using epoxy resin, the hydrated alumina effectively prevents creepage failure when present in the amount of 20 to 70% by weight of the insulation and preferably 40 to 70%.

While we do not wish to be bound by any particular theory, it being sufficient that our invention accomplishes the desired end, we believe that the combined water in the hydrated alumina serves to oxidize the carbonaceous particles formed under creepage conditions and that the aluminum oxide component itself acts as a catalytic agent to indirectly promote this oxidation. It has been found that while unhydrated aluminum oxide is useful in delaying tracking under surface creepage conditions, it is not efficacious in oxidizing carbonaceous materials or in preventing the eventual failure of insulation due to creepage tracking. It has also been found that the water must be chemically bound to the aluminum oxide as in the hydrated compound. It will be obvious that in practical commercial applications, failure due to surface creepage tracking must be not merely delayed but wholly eliminated as by the practice of our invention.

In order that those skilled in the art may better understand how the present invention may be practiced, the following examples are given to illustrate organic insulation components containing epoxy resin materials coming within the scope of this invention. These examples are given by way of illustration and not by way of limitation.

Example I

Tests were conducted with apparatus mock-ups including epoxy resin insulating compositions and selected

concentrations by weight of hydrated alumina of the chemical composition $Al_2O_3 \cdot 3H_2O$. Test sheet samples of epoxy resin about 0.075" in thickness were cast and mold cured at 125° C. for about one hour, the particular epoxy resin being a Shell Chemical Company epoxy resin known as Epon 828, the catalyst used being 8.5% by weight of diethylenetriamine based on the weight of the epoxy resin. The tests were conducted in accordance with the procedure set forth below, the samples being identified by the numeral 21 in FIG. 3 being mounted in a high voltage test cage resting flat against a conducting metal plate 22 tilted at an angle of about 15° from the horizontal.

Two electrodes 23 and 24, each about 1" by 2" in cross section were placed perpendicularly against the surface of each sample 21 under test, that is, against the upper side of the sample opposite that in contact with the metal plate 22. The electrodes 23 and 24 were positioned about 1" apart with the 2" dimensions of the electrodes extending parallel to each other. One of the two electrodes, identified by numeral 23, was connected to the metal plate 22 by clips 25 and 26 and conductor 27. The two electrodes were electrically connected across the alternating voltage output of an adjustable high-voltage transformer through clips 28 and 29. It will be appreciated that, with the circuit just described, creepage breakdown of the sample may occur between the two electrodes 23 and 24 or between electrode 24 and the metal plate 22 by means of a surface failure, or between electrode 24 and the metal plate 22 through the thickness of the sample by means of an erosion type failure.

After the test samples were placed in the apparatus as just described, they were dusted with a synthetic dust representative of atmospheric dust accumulations, the dust particles being designated by reference character 30. A fine water spray 31 was directed against the samples for the duration of the test, a nozzle 32 being coupled with water and air lines 33 and 34 for this purpose. A 60-cycle voltage of about 1500 volts was applied to the electrodes 23 and 24 to set up surface discharge conditions of the intensity capable of causing decomposition of organic materials. The samples were removed from the apparatus for redusting purposes at the end of each 100 hours of testing, or sooner for inspection purposes if failure occurred.

It will be observed by referring to the dust-spray test data presented, that a large increase in operating life of the apparatus under electrical discharge conditions is obtained as the concentration of hydrated alumina is increased beyond a certain level. A more significant consideration is, however, the concentration level at which the type of failure encountered changes from a "surface" type failure to an "erosion" type failure.

The surface failure is one which occurs by reason of formation of a random carbon path along the surface of the material indicating that the life of the material is being limited by carbonization, while an erosion failure is one which occurs because the insulation component 21 is reduced in thickness by an eroding effect not involving carbonization. That is, it is determined by the inherent qualities of the insulation component itself rather than by some external cause such as carbonization.

Hence, at the point where erosion failure begins to occur instead of surface failure, the concentration of hydrated alumina has reached a level where carbonization is no longer the limiting factor with respect to ability of the high-voltage apparatus to withstand creepage electrical discharges. The samples used to obtain the data presented were inspected upon failure to determine the type of failure involved in each case; that is, whether breakdown occurred across the surface through carbonization or whether it occurred through the thickness thereof by erosion between the ungrounded electrode 24 and the metal plate 22.

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The results of the above tests are tabulated below.

TABLE I

Material	Percent $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$	Hours to Failure	Type of Failure
Shell Chemical epoxy resin No. 828.	0	Less than 1.....	Surface.
	20	18.....	Surface and Erosion.
	30	Greater than 200....	Erosion.
	40	do.....	Do.
	50	do.....	Do.
	66	do.....	Do.

It is noted that with this epoxy resin, the critical concentration of $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$, that is, the concentration level where carbonization is no longer the limiting factor on operating life, is also in excess of 25% by weight of the total insulation.

Example II

Example I was repeated using as the curing agent triethanolamine in the amount of 12.5% by weight of the resin. The results of tests conducted as in Example I in this material are tabulated below:

TABLE II

Material	Percent $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$	Hours to Failure	Type of Failure
Shell Chemical epoxy resin No. 828.	0	Less than 1.....	Surface.
	10	1.....	Do.
	20	10.....	Do.
	30	Greater than 200....	Erosion.
	40	do.....	Do.
	50	do.....	Do.

Example III

Example I was repeated using as the epoxy resin Araldite No. 6010 made by Ciba Company and as the curing agent 12.5% by weight of triethanolamine based on the weight of the resin. When tested as in Example I the results were as follows:

TABLE III

Material	Percent $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$	Hours to Failure	Type of Failure
Ciba Company Epoxy resin Araldite 6010.	0	2.....	Surface.
	10	1/2.....	Do.
	20	100.....	Surface and Erosion.
	30	Greater than 200....	Erosion.
	40	do.....	Do.
	50	do.....	Do.

Example IV

Example I was repeated using phthalic anhydride in the amount of 40% by weight of the resin as the curing agent for Shell Chemical Company epoxy resin No. 828. When these materials were tested as in Examples I and III, the results were as follows:

TABLE IV

Material	Percent $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$	Hours to Failure	Type of Failure
Shell Chemical Co. epoxy resin No. 828.	0	Less than 1.....	Surface.
	10	2.....	Do.
	20	3.....	Do.
	30	35.....	Surface and Erosion.
	40	150.....	Do.
	50	Greater than 200....	Erosion.
	60	do.....	Do.
	70	do.....	Do.

Example V

Example I was repeated using as the curing agent for Ciba Company epoxy resin 6060, phthalic anhydride in

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the amount of 30% by weight of the resin. When tested as in Examples I and III, the results were as follows:

TABLE V

Material	Percent $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$	Hours to Failure	Type of Failure
Ciba Company epoxy resin Araldite 6060.	0	Less than 1.....	Surface.
	10	1.....	Do.
	20	2.....	Do.
	30	11.....	Do.
	40	30.....	Surface and Erosion.
	50	Greater than 200....	Erosion.
	60	do.....	Do.

It will be noted from the above examples directed to epoxy resins that in general the amine type curing agents produce insulating materials according to this invention which are more resistant at lower hydrated alumina concentrations to creepage failure than epoxy resins cured with acid anhydrides, it being necessary with the latter curing agent to add relatively more hydrated alumina to afford protection. It will be also noted that from about 20% to 70% of hydrated alumina based on the total weight of the material provides insulation which prevents creepage under the dust-spray test. In the salt fog test described hereinbefore about 40% by weight or more of the insulation must be hydrated alumina in order to wholly eliminate creep tracking. The upper proportion of hydrated alumina is limited only by the physical characteristics of the insulation.

The term "epoxy resin" or "ethoxylene resin" as used herein is intended to mean a complex epoxide resin comprising a polyether derivative of a polyhydric organic compound, e.g., polyhydric alcohol or phenols containing at least two phenolic hydroxy groups, said derivatives containing 1,2 epoxy groups. The ethoxylene resins as defined are disclosed in various places in the art such as in Castan Patent 2,324,483 as well as Castan Patent 2,444,333, British Patent 518,057 and British Patent 579,698. U.S. Patents 2,494,295; 2,500,600; 2,511,913 and 2,691,007 disclose other examples of ethoxylene resinous compositions falling within the definition. Curing of such compositions is readily accomplished by acidic (e.g., phthalic anhydride, etc.) or strongly alkaline materials (e.g., diethylene triamine, etc.).

It will be apparent that the particular examples set forth above by way of illustration are not limiting in nature and that various forms of electrical apparatus having greatly improved resistance to breakdowns caused by creepage electrical discharges may include insulation components having the organic insulating materials set forth above and a hydrated alumina in concentration defined by the foregoing disclosure, and that such arrangements deriving the advantages of our invention, will fall within the true scope and spirit of our invention as defined in the appended claims.

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

1. Electrical apparatus comprising at least two spaced electrically conducting members between which electrical potentials may be developed, an organic insulating material disposed and completely filling the space between said members and having an outer surface intermediate said members exposed to ambient contaminating atmospheric conditions, said surface material comprising epoxy resin which tends to form low resistance carbonaceous deposits under the influence of creepage type electrical discharges occurring under contaminating conditions and means for preventing the formation of said carbonaceous deposits due to creepage, said means comprising hydrated alumina interspersed in said surface material in the amount of from 20 to 70 percent based on the weight of said surface material and hydrated alumina.

2. Molded electrical apparatus comprising at least two electrically conducting members between which electric

potentials may be developed and an insulating composition disposed between said members and having an outer surface intermediate said members exposed to ambient contaminating atmospheric conditions and fixing said members in spaced relationship such that electrical discharges of the creepage type may occur therebetween and across said surface of said insulating composition, said composition including epoxy resin which leaves a low resistance carbonaceous residue under influence of creepage type electrical discharges and further including hydrated alumina interspersed in said composition in the amount of from 20 to 70 percent based on the weight of said composition and hydrated alumina, said hydrated alumina preventing accumulation of carbonaceous material upon exposure of said surface of said insulating composition and hydrated alumina to creepage type electrical discharges occurring across said surface under contaminating conditions.

3. An electrical insulator shaped to support and hold in insulating relationship a plurality of conducting members which are adapted to have electrical potentials developed thereacross and between which electrical discharges of the creepage type may occur, said insulator comprising an organic insulating material disposed between said members and having an outer surface intermediate said members exposed to ambient contaminating atmospheric conditions, said surface material comprising epoxy resin which tends to form low resistance carbonaceous deposits under influence of creepage type electrical discharges and hydrated alumina dispersed in said surface material and comprising from about 20 to 70 percent by weight of the combined surface material and hydrated alumina, said hydrated alumina serving to prevent the formation of said carbonaceous deposits under said contaminating conditions.

4. Electrical apparatus comprising at least two spaced electrically conducting members between which electrical potentials may be developed, an organic insulating material disposed and completely filling the space between said members and having an outer surface intermediate said members exposed to ambient contaminating atmospheric conditions, said surface material comprising epoxy resin which tends to form low resistance carbonaceous deposits under the influence of creepage type electrical discharges occurring under contaminating conditions and means for preventing the formation of said carbonaceous deposits due to creepage, said means comprising hydrated alumina interspersed in said surface material in the

amount of 60 percent based on the weight of said surface material and hydrated alumina.

5. Electrical apparatus comprising at least two spaced electrically conducting members between which electrical potentials may be developed, an organic insulating material disposed and completely filling the space between said members and having an outer surface intermediate said members exposed to ambient contaminating atmospheric conditions, said surface material comprising epoxy resin which tends to form low resistance carbonaceous deposits under the influence of creepage type electrical discharges occurring under contaminating conditions and means for preventing the formation of said carbonaceous deposits due to creepage, said means comprising hydrated alumina interspersed in said surface material in the amount of from 40 to 70 percent based on the weight of said surface material and hydrated alumina.

6. In a molded electrical transformer adapted to be energized by a source of electrical power and having spaced high voltage terminals and low voltage terminals, an insulating material molded about said transformer and fixedly positioning said terminals, said material being disposed and completely filling the space between said terminals and having an outer surface intermediate said high and low voltage terminals exposed to ambient contaminating atmospheric conditions, the improvement which comprises at least the outer surface of said material including epoxy resin which leaves a conducting carbonaceous deposit under the influence of creepage electrical discharges and hydrated alumina dispersed in at least said outer surface of said material to comprise from 20 to 70 percent by weight of at least said outer surface of the combined insulating material and said hydrated alumina, said hydrated alumina obviating said carbonaceous deposits.

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