April 15, 1947. G. F. COGGINS ET AL 2,418,820

ART OF DIELECTRICS

Filed July 7, 1942 2 Sheets-Sheet 1

Fig. 1.

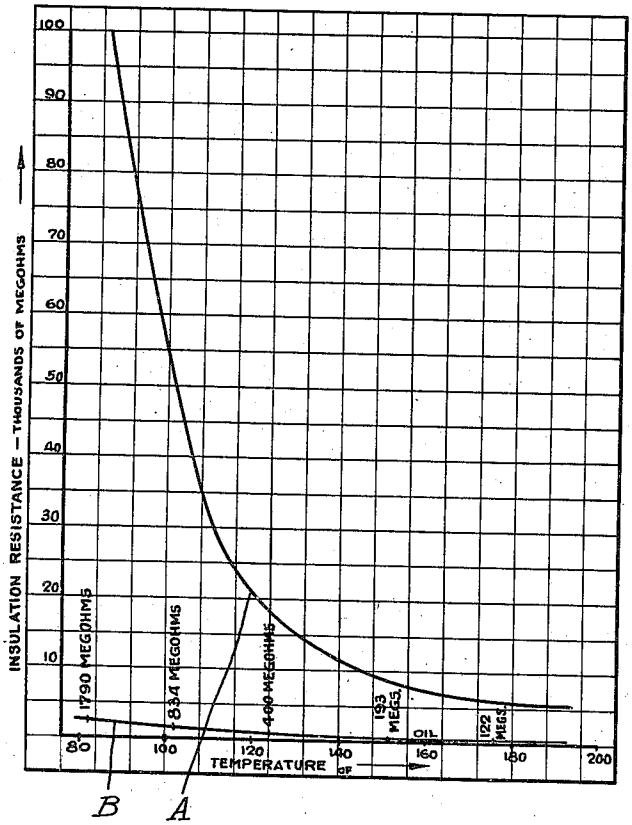
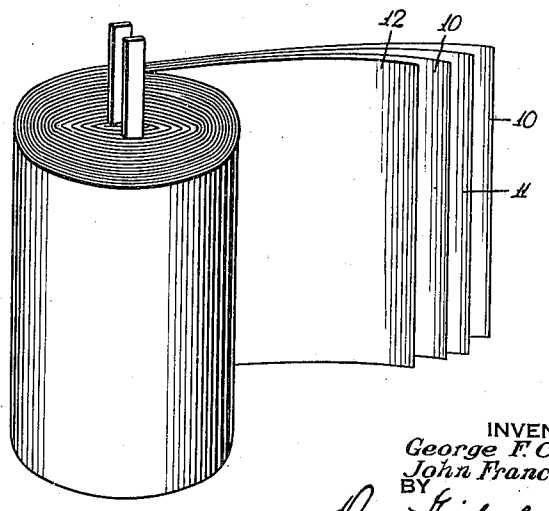


Fig. 2.



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Fig. 3.

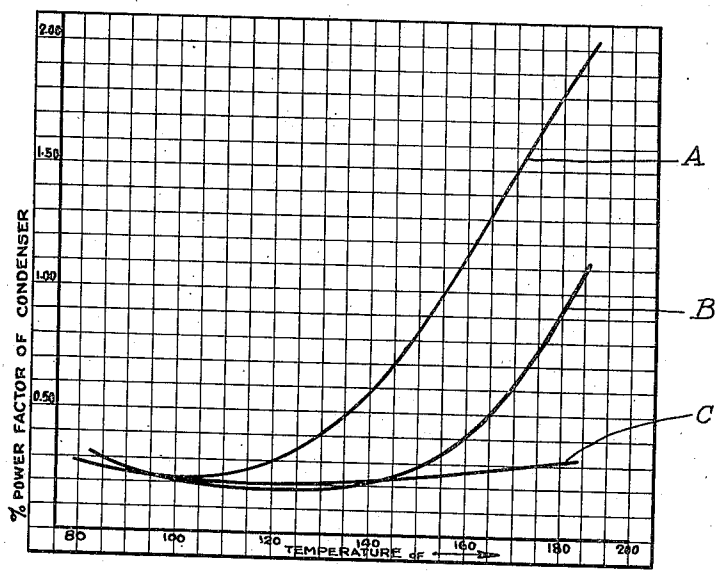
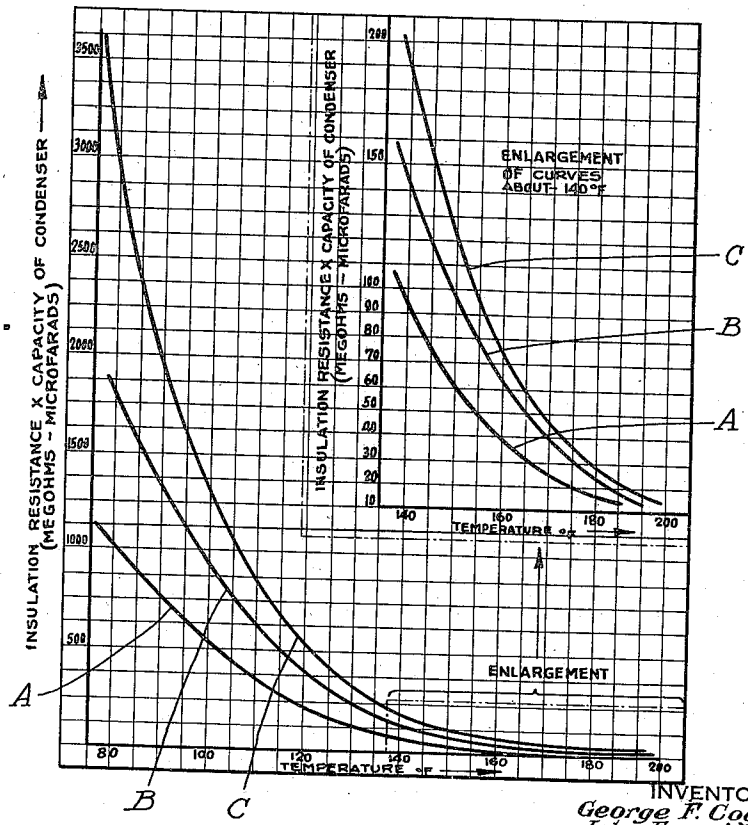


Fig. 4.



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ART OF DIELECTRICS

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Application July 7, 1942, Serial No. 450,095

6 Claims. (Cl. 252—64)

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The present invention is concerned with dielectrics and with apparatus especially with electrostatic condensers incorporating the same.

More specifically, the invention relates to dielectric compositions consisting wholly or partly of castor oil, and to electrical condensers in which castor oil or a mixture containing castor oil is utilized as the dielectric impregnating medium.

As conducive to a clear understanding of the invention, it is noted that the life of paper-wound dielectric condensers incorporating castor oil as a dielectric impregnating medium is relatively short, due to the rapid deterioration of the castor oil under heat and electrical stress, and the performance thereof is inferior at high temperatures, at which the insulation resistance drops to relatively low values, and power losses increase to relatively high percentages.

One of the objects of the present invention is to provide a condenser with a dielectric component of castor oil, which presents certain radical improvements in performance, including some or all of the following: (1) greatly enhanced stability to the combined effects of heat and electrical stress, (2) greatly improved insulation resistance (3) radical improvement in the power factor particularly at high temperatures (4) tremendously increased life under severe conditions of use, all as compared with condensers incorporating ordinary so-called "chemically pure" castor oil of commerce, as a component of the dielectric, these various improvements to be achieved without sacrifice of any of the advantages of similar equipment incorporating the best grades of castor oil of commerce.

Another object is to provide a castor oil impregnant for electrical condensers which brings to pass the various improvements set forth above in the performance of an electrostatic condenser incorporating the same, as compared with one using castor oil of commerce for the purpose.

Another object is to provide a castor oil dielectric which itself presents a radical improvement in electrical characteristics as compared with chemically pure castor oil of commerce in that the power factor is much lower and the insulation resistance is greatly multiplied, both of said improvements being manifested over a wide range of temperature.

One of the components of castor oil of commerce which has a deleterious effect on the electrical characteristics of a condenser incorporating the same is free fatty acid. Calculated as oleic acid, even in chemically pure castor oil of commerce, this content is seldom less than .45 per cent. According to the present invention in one of its aspects, the improvements in insulation resistance, life, and power factor of condensers, which are among the objects of the invention, are achieved by substituting in place of the conventional castor oil impregnant containing a substantial percentage of free fatty acid a new impregnant which differs from the conventional type in that substantially all of the free acid detectable by the usual chemical tests has been removed therefrom. As a variation within the scope of the invention, a castor oil impregnant may be used containing a predetermined percentage of free fatty acid lower than the minimum ordinarily present in so-called "chemically pure" castor oil of commerce. Such practice will result in an improvement in condenser quality as determinable by accepted methods of test, but the improvement will not be so great as that which results from the use of an impregnant substantially free of uncombined acid.

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Another class of constituents of chemically pure castor oil of commerce which have a deleterious effect on the electrical characteristics both of the oil itself and of condensers utilizing the oil as impregnant are those compounds which are removable by certain adsorbents such as fuller's earth, bentonite, and certain other activated clays and activated carbons.

It has heretofore been common practice in the art to treat castor oil with adsorbent in order to obtain a product of resistivity sufficiently high and of power factor sufficiently low to serve as a reasonably satisfactory condenser impregnant. However, it has not heretofore been appreciated that vast improvements in various electrical properties of the dielectric and multiplication in the life of the condenser incorporating the same, as compared with the results of the conventional adsorbent treatment could be attained if the oil be subjected to a true refining procedure, for removal of virtually all constituents which we have found to be injurious to the electrical properties and capable of removal by the particular adsorbent used.

We have found that by controlling such variables involved in the adsorbent treatment as kind and quantity of adsorbent, number of treatments, temperature, and time, the dielectric qualtities of the oil as determined by accepted methods of test may be improved to the vast extent indicated to a maximum point beyond which further treatment with adsorbent gives little or no detectable additional improvement. A preferred process for achieving this result is the subject of our copending application above identified. We have found that castor oil treated in this way to remove substantially all deleterious adsorbable components has outstanding electrical characteristics, such as resistivity and power factor, and is vastly superior to the ordinary castor oil of commerce when used as an impregnating medium for electrical condensers, in that greatly improved insulation resistance, power factor, and life are obtained for condensers so impregnated. In fact, the improvement in electrical characteristics is so great as to set the processed oil apart as a composition of matter having new and distinctive properties, which will be described in detail later on in the specification.

The adsorbent treatment invented by us can be carried out either on castor oil of commerce containing free fatty acid or on castor oil from which free acid has been either completely or partially removed in manner taught by us. In either case a product will be obtained having remarkably improved resistivity and power factor as compared with chemically pure castor oil of commerce, as will be apparent from typical measurements given later on in this specification. However, when both free acid and adsorbable components are removed, a product is obtained which has extremely unusual value as an impregnant for electrical condensers. The removal of both free acid and adsorbable components from the impregnant results in a greater improvement in insulation resistance, life, and power factor than is possible through the removal of only one of these classes of deleterious constituents. But in addition, condensers impregnated with oil from which both free acid and adsorbable components have been virtually completely removed are found to exhibit a remarkable constancy of power factor over a very wide temperature range, so that power factor at, say 185 degrees F. is approximately the same as at room temperature.

Suitable processes for the removal of adsorbable constituents with or without the removal of free acid from castor oil and related substances are described and claimed in our copending application, Serial No. 450,094, filed July 7, 1942.

Stated in sketchy outline, the process of acid removal set forth in said copending application comprises neutralizing the acid by the addition of aqueous alkaline solution, followed by the removal of the foots or a substantial part thereof from the castor oil by absorbent treatment in the absence of further added water. The removal of those adsorbable constituents that are deleterious to the electrical characteristics such as resistivity and power factor is effected by adsorbent treatment, until electrical measurement as of resistivity or power factor shows that an optimum condition has been reached that cannot be noticeably improved by further treatment.

The improved dielectric structure as an article of manufacture, and the dielectric material as a composition of matter, alone are claimed in this application, and the dielectric is not to be limited

to any particular process by which the same may be prepared. Nor is the dielectric structure to be limited to any particular design of condenser, provided the improved dielectric impregnant be incorporated therein.

In the accompanying drawings in which those aspects of the invention capable of illustration are shown:

Fig. 1 is a graph showing the improvement at various temperatures in the insulation resistance of the castor oil dielectric achieved by virtually complete removal of the deleterious adsorbable components,

Fig. 2 is a perspective view of a conventional condenser section partly opened,

Fig. 3 is a graph showing the improvement at various temperatures in the power factor of the condenser, and

Fig. 4 is a similar graph showing the improvement in the product of insulation resistance and capacity of the condenser.

The improvement in the insulation resistance of a typical batch of castor oil substantially freed of those adsorbable components which have a deleterious effect on electrical properties is illustrated in Fig. 1, in which curve A represents the new oil and curve B a sample of the commercial castor oil from which the treated oil of curve A was prepared. At 87 degrees F., for instance, the new oil had a resistivity of 100,000 megohms, while the commercial oil had only 1500 megohms. (Insulation resistance as referred to herein was determined by filling the air space of a fixed air condenser of 107 micro-microfarads capacity and air gap of .078 inch with the dielectric material to be tested and measuring the current in microamperes at 500 volts D. C. after two minutes. The test condenser referred to is a product of Bud Radio, Inc., Cleveland, Ohio, and is listed under catalog No. FA 782.) At higher temperatures there is a corresponding improvement; the treated oil at 185 degrees F. tested about 6000 megohms, the untreated only 122.

The megohm measurements on the Bud Radio test condenser must be multiplied by the constant 1.1×10^9 to convert them to the resistance measurement in ohms per cubic centimeter. Thus 2,000 megohms on the Bud test condenser become 2.2×10^{12} on the ohms per centimeter^3 scale.

The graph of Fig. 1 is to be regarded as typical of such oil free of adsorbable matter, regardless of whether or not free fatty acid be present, since the small quantities of the latter ordinarily present do not greatly affect the resistivity of the oil, although as is apparent from the graphs of Figs. 3 and 4 such fatty acid does have considerable effect on resistance and power factor of condensers in which the oil is used as impregnant.

The resistivity of commercial castor oil, it should be understood, is subject to wide variation. We have examined samples which tested as low as 1500 megohms and as high as 9000 megohms at room temperature. Samples of oil of the present invention have been prepared which at room temperature gave no deflection at 500 volts D. C. on a microammeter reading to .01 microampere, and which had a resistivity of 10,000 megohms at 185 degrees F.

The oil from which the adsorbable matter has been substantially completely removed, also possesses an improved power factor. By way of comparison, a sample of good quality castor oil of commerce (Baker's D. B.) having insulation resistance of 2000 megohms at 80 degrees F. and fatty acid content of .88 per cent (as oleic) had

a power factor of .03 per cent at 80 degrees F. and .33 per cent at 185 degrees F. The power factor of the same oil after substantially complete removal of adsorbable components power factor measured on 1000 cycles A. C. was found to be in the order of .01 per cent in the temperature range from 80 degrees F. to 185 degrees F.

In Fig. 2 is illustrated a conventional condenser section partly opened, which comprises a roll made up of paper dielectric 10 interposed between and superposed over conventional foil electrodes 11 and 12, the paper being impregnated with the castor oil processed as above set forth.

The data summarized in the graphs of Figs. 3 and 4 were obtained on condenser sections of the type illustrated in Fig. 2 which had been impregnated in accordance with the following typical procedure. The wound sections were dried thoroughly at 250 degrees F. under a vacuum of approximately 200 microns mercury. The impregnating oil was then run in through clean conduits while maintaining a vacuum of 400 microns or better. The sections were allowed to remain in oil for several hours at about 180 degrees F. under a vacuum of approximately 100 microns. Finally, the vacuum was broken and the sections were removed from the impregnator and sealed in metal containers filled with fresh oil of the same kind as was used for impregnation.

The extent of the improvement in the power factor of the condenser incorporating the new castor oil impregnant will appear clearly from the graph of Fig. 3. As there shown, the power factor of a condenser such as shown in Fig. 2 impregnated with ordinary untreated chemically pure castor oil of commerce (represented by curve A) changes with temperature, from approximately 0.3 per cent at 80 degrees F. beginning to rise rather steeply at approximately 115 degrees F. until at 180 degrees F. the power factor is about six times as great, having a value of approximately two (2.0) per cent. On the other hand, the condenser impregnated with like castor oil from which both free fatty acid and adsorbable components had been virtually completely removed (curve C, Fig. 3) was found to have a power factor which remains substantially constant throughout the range between 80 degrees and 180 degrees F. That power factor is approximately equal at 80 degrees F. to that of the condenser impregnated with untreated chemically pure castor oil, but remains at substantially that value throughout the range to 180 degrees F. and thus is six times better at the higher temperature than is the condenser impregnated with the untreated chemically pure castor oil of commerce.

There is also plotted a curve (curve B, Fig. 3) showing the power factor of a condenser impregnated with the improved castor oil dielectric, substantially freed of deleterious components capable of removal by adsorbent but containing .78 per cent free fatty acid calculated as oleic. The condenser impregnated with such improved dielectric oil shows a marked improvement as compared with one incorporating the chemically pure castor oil of commerce, in that the power factor curve shows little change from 80 degrees F. to 145 degrees F., although that of the condenser made with commercial oil rises steeply beginning at about 115 degrees F. At temperatures above 145 degrees F. there is also manifested a marked improvement, so that the improved impregnant gives a condenser which at 180 degrees F. has about twice as good a power factor as a similar

one incorporating the ordinary commercial castor oil.

In Fig. 4 the product of insulation resistance by capacity is shown plotted against temperature. Curve A represents the condenser impregnated with the untreated chemically pure castor oil of commerce, curve B represents the condenser impregnated with the same oil substantially freed of deleterious adsorbable components but containing some free fatty acid, and curve C the condenser impregnated with the same oil freed of substantially all uncombined acid as well as of all deleterious adsorbable matter. It is generally considered by those skilled in the art, that the product of insulation resistance by capacity should be as high as possible. It is seen that while with the untreated oil, the condenser at 80 degrees F. has a value of 1000 megohms-mfds., with the impregnant freed of both uncombined acid and adsorbable constituents the condenser has a corresponding value at that temperature of close to 3000 megohms-mfds., while with the impregnant freed of adsorbable compounds but not freed of uncombined acid, such condenser has a value of close to 1800 megs.-mfds. at the same temperature of 80 degrees F. Throughout the temperature range up to 180 degrees F. and higher, the products of insulation resistance by capacity of condensers incorporating the three types of impregnant have roughly the same relative values, although the absolute values decrease. From the enlargement of the curves between the range of 140 degrees F. and 200 degrees F., in which the ordinates are magnified about twelve to one, it is seen that the relative excellence of the condensers impregnated with the respective dielectrics is roughly maintained. The condenser with the commercial oil has a product of insulation resistance by capacity at 140 degrees F. of 90 megohm-mfds., while the condenser made with the oil freed of both adsorbable matter and uncombined acid has a value of 190 meg.-mfds., and that made with the oil freed only of adsorbable matter has a value of 140 megohm-mfds. At 180 degrees F. the condensers impregnated with the three different types of impregnant have values of 16 megohms-mfds., 28 megohms-mfds., and 25 megohms-mfds., respectively.

Condensers impregnated with the improved dielectric material of the present invention have been tested to determine probable life in operation by a procedure which consists in placing the condensers on alternating current at two and one-half times the rated voltage at a temperature of 185 degrees F. until breakdown occurs. Condensers impregnated with oil that had been substantially freed of those adsorbable components that have an adverse effect on electrical characteristics and freed also of all but in the order of .05 per cent uncombined fatty acid had a life on such test, of more than three times that of similar condensers impregnated with chemically pure castor oil of commerce, while condensers made with castor oil freed of adsorbable matter but containing the usual amount (.45 per cent or more) of free fatty acid lasted more than twice as long as the conventional castor oil condenser.

These figures are given for purposes of comparison and are not to be construed as fixed values, because as is well known in the art, tests of this nature are influenced by a large number of difficultly controlled variables, of which quality of impregnant is only one. However, re-

peated tests of this kind indicate that the figures given above represent an approximate minimum improvement in life expectancy of condensers made with the impregnants claimed as the present invention.

Although the present specification has concerned itself chiefly with improved castor oil dielectrics of two basic types, namely (1) castor oil from which substantially all free acid and deleterious adsorbable components have been removed, and (2) castor oil virtually free of all adsorbable components which would have an adverse effect on its electrical properties, though not entirely free of acid, it is evident that the advantages claimed for these two types of improved dielectric may be obtained in a lesser degree by less complete removal of either or both of the two classes of constituents named. For example, a castor oil dielectric may be prepared substantially free of uncombined fatty acid but containing a moderate amount of adsorbable constituents the more complete removal of which would result in a further improvement in dielectric qualities, although certain considerations as that of cost may make it inadvisable to effect such complete removal in a particular application. Such a dielectric would come within the scope of the present invention from its broader aspects as would also a condenser using such material as impregnant.

In other cases it may be desirable to make condensers with an impregnant of castor oil which contains a small percentage of free fatty acid, less than the best grade of ordinarily "chemically pure" castor oil of commerce, but more than above set forth. In such cases the adsorbable matter present may, depending on the quality of product desired, be about the same as that found in commercial oil, or the adsorbable matter may be either partially or substantially completely removed. Such improvements in condenser quality as result from the use of such improved impregnant, even though the improvement in impregnant quality does not achieve the maximum described in the foregoing specification, are claimed as within the scope of the present invention from its broader aspects.

It will of course be understood that while in general the dielectric composition as above set forth is preferred, dielectric containing a substantial proportion of such composition admixed with other dielectric materials would come within the scope of the present invention as defined in the claims.

While the application is concerned chiefly with castor oil in the present invention, as the impregnant of the paper or other oil absorbent cellulosic material it is to be understood that in its broader aspects, the principles of the invention are applicable to fatty acid esters or mixtures thereof such as vegetable oils or waxes, and also to other fatty acid derivatives such as ketones. Said principles are applicable not only to such oils and waxes of natural origin but also to the respective characterizing component thereof or their homologues whether derived from the natural product or synthetically prepared. The really vitalizing component thereof, namely, glycerol tri-ricinoleate may be used to advantage in place of castor oil. Instead of glycerol tri-ricinoleate other ricinoleates may be used in like manner and will show decided improvement in some or all of the respects noted. In general, the principles set forth in the foregoing lead to marked improvement in the dielectric structure as compared with the results attained by the use of the corresponding compound having present therein either or both free fatty acid and adsorbable matter deleterious to electrical properties.

As many changes could be made in the above dielectric and apparatus and many apparently widely different embodiments of this invention could be made without departing from the scope of the claims, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

We claim:

1. A dielectric structure comprising absorbent cellulosic material impregnated with castor oil that is substantially free of those constituents that admit of removal by treatment with fuller's earth, said castor oil having a power factor of less than .05 per cent measured on 1000 cycles at 185 degrees F. and a resistivity of more than 10^{12} ohms per cubic centimeter at 185 degrees F., such structure when incorporated in a capacitor being characterized by greatly improved insulation resistance, power factor and life.

2. A dielectric structure of paper impregnated with castor oil having less than the .4 per cent free fatty acid therein calculated as oleic acid, said castor oil having present therein in minor quantities only, those constituents that admit of removal by treatment with fuller's earth and said castor oil having resistivity at 185° F. greater than 3×10^{11} ohms per cubic centimeter, said impregnated structure being characterized by greatly improved insulation resistance and power factor when incorporated in a capacitor.

3. A dielectric structure comprising absorbent cellulosic material impregnated with castor oil that is substantially free of those constituents that admit of removal by treatment with fuller's earth, said castor oil being also substantially devoid of free fatty acid, and having resistivity greater than 10^{12} ohms per cubic centimeter at 185 degrees F. and a power factor less than .05 per cent at 185 degrees F. said structure when incorporated in a capacitor being characterized by greatly improved insulation resistance, power factor and life.

4. A dielectric structure comprising absorbent cellulosic material impregnated with alkyl ricinoleate, having therein as impurity less than .4 per cent free fatty acid calculated as oleic acid, said structure when incorporated in a capacitor being characterized by greatly improved insulation resistance, power factor and life.

5. A dielectric structure comprising absorbent cellulosic material impregnated with glycerol triricinoleate having present therein as impurity less than four tenths of one per cent free fatty acid calculated as oleic acid, said ricinoleate having specific resistivity greater than 3×10^{11} ohms per cubic centimeter at 185° F. and power factor less than one tenth of one per cent at 185° F., said structure when incorporated in a capacitor being characterized by greatly improved insulation resistance, power factor and life.

6. A di-electric structure comprising absorbent cellulosic material impregnated with glycerol triricinoleate that is substantially free of those impurities that admit of removal by fuller's earth, said ricinoleate having specific resistivity greater than 3×10^{11} ohms per cubic centimeter at 185 degrees F. and power factor less than .2 per cent at 185 degrees F., said structure when incor-

porated in a capacitor being further characterized by greatly increased life.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,241,926	Cordes	Oct. 2, 1917
1,372,632	Schwarcman	Mar. 22, 1921
1,548,838	Harvey	Aug. 11, 1925
1,576,096	Davey	Mar. 9, 1926

OTHER REFERENCES

The Electrochemical Society, Preprint 65–11 Some General Properties of Liquid Organic Dielectrics by Vladimer Karapetoff, Apr. 26, 1934, page 125. (Copy in Div. 64.)

Handbook of Chem. and Physics, Hodgman, 14th ed., 1929, p. 474.

Chem. Technology, etc., Lewkowitsch, 6th ed., vol. II, 1922, The MacMillan Co., New York, page 406.

"Electrical Condensers," by Coursey, 1927, Pub. by Pittman & Sons Ltd., pp. 88 to 96. (Copy in Div. 48.)

"Journal of Scientific Insts.," Sept. 1942, vol. 19, #9, pp. 129–136 by Wearmouth.

"Elec. World," June 12, 1943, vol. 119, #24, pp. 69–71 by Carswell.