Feb. 16, 1965 J. G. FORD 3,170,027

TREATED CELLULOSIC INSULATION AND ELECTRICAL APPARATUS EMBODYING THE SAME

Filed Jan. 3, 1962

Fig. I.

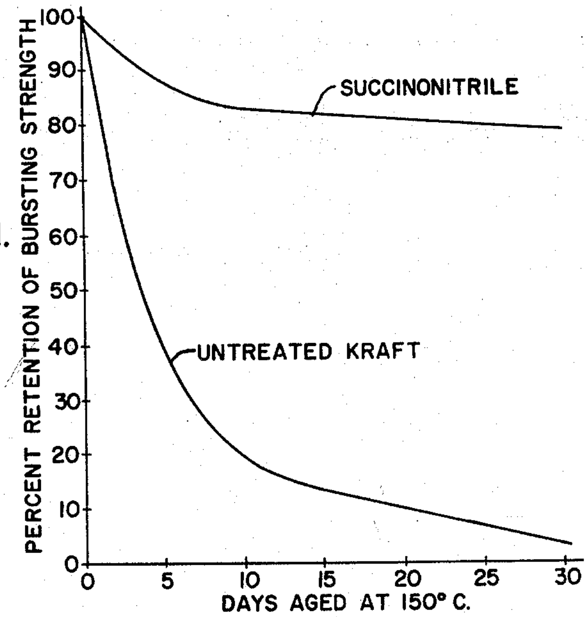
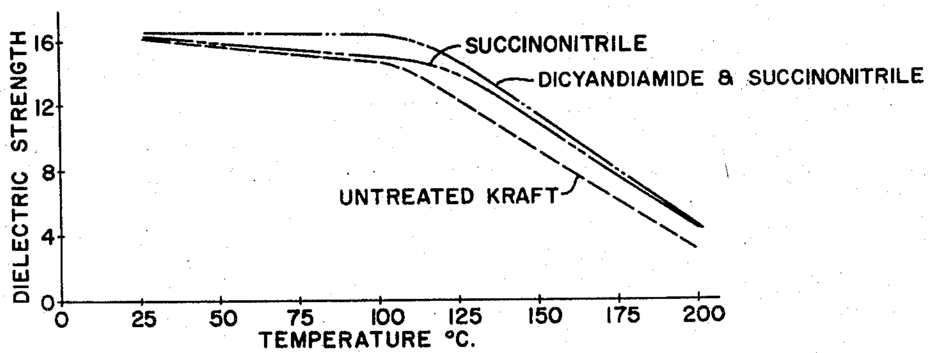


Fig. 2.



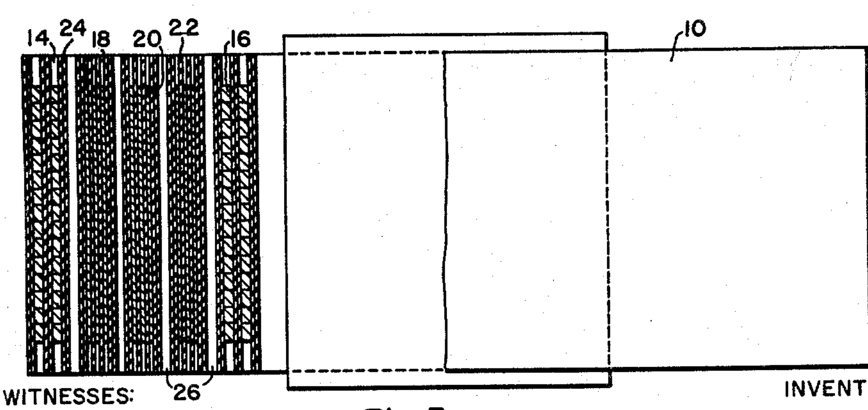


Fig. 3.

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United States Patent Office 3,170,027 Patented Feb. 16, 1965

3,170,027

TREATED CELLULOSIC INSULATION AND ELECTRICAL APPARATUS EMBODYING THE SAME

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Filed Jan. 3, 1962, Ser. No. 164,113
12 Claims. (Cl. 174—17)

The present invention relates to cellulosic insulation which is particularly adapted for use in electrical apparatus. The invention further relates to cellulosic insulation characterized by greatly improved electrical insulating properties and thermal stability. The invention relates to the improved cellulosic electrical insulation and to electrical apparatus insulated therewith.

The present application is a continuation in part of my copending application Serial No. 839,166, filed September 10, 1959.

Cellulosic materials such as paper, cotton cloth, cotton tape, pressboard and wood have long been employed in the electrical industry as insulation for various components of electrical apparatus. Such materials represent a desirable source of electrical insulation from the standpoint of their economic advantages over other available types of insulation. Moreover, cellulosic insulation possesses adequtae physical properties and satisfactory initial dielectric strength.

However, cellulosic materials deteriorate rapidly at temperatures appreciably above 100° C. when in contact with air, and this deterioration is much more pronounced in the presence of liquid dielectrics. Both the physical and electrical properties are affected with the result that the insulation rapidly loses its electrical insulating strength and its retained mechanical strength is rapidly dissipated.

The electrical and thermal properties of cellulosic materials such as paper, cotton cloth, cotton tape, and wood deteriorate rapidly at temperatures above 100° C. when in contact with air or fluid dielectric compositions. Thus, for example, after being immersed for only a few weeks in highly refined petroleum transformer oil at 120°–150° C., paper will retain only a few percent of its original dielectric strength and practically none of its original tensile strength. Generally, a length of fresh electrical grade kraft paper may be bent or flexed several hundred times before it will break. However, after only a few days immersion in transformer oil at 150° C. it will break upon being folded double once. For these reasons, it has been specified that, in electrical apparatus employing cellulosic insulation, the continuous operating temperatures shall not exceed about 105° C.

It has now been discovered there are certain nitrogen-containing nitrile compounds which not only greatly improve the thermal stability of cellulosic insulation but, entirely unexpectedly, impart to the insulation outstandingly improved electrical properties. The properties are not only apparent in the presence of liquid dielectric compositions but are obtained as well when the insulation is employed in an atmosphere of air or other gas.

It is therefore a primary object of the invention to provide cellulosic electrical insulation containing nitriles and characterized by both improved thermal stability and outstanding electrical properties.

A further object of the invention resides in the provision of cellulosic electrical insulation containing effective amounts of certain nitrile chemical stabilizing compounds.

Other objects of the invention will become apparent from the following detailed description thereof. The description will be given with particular reference to the accompanying drawings, in which:

FIG. 1 is a graph plotting Mullens bursting strength against days of aging of stabilized and unstabilized kraft paper in transformer oil at 150° C.;

FIG. 2 is a graph plotting dielectric strength retention of stabilized and unstabilized kraft paper aged in transformer oil at 150° C.; and

FIG. 3 is a view in perspective, partly in section, of a transformer core insulated with the novel cellulosic insulation of the invention.

In accordance with the present invention, it is now possible to increase greatly the retention of both dielectric strength and mechanical strength of cellulosic insulation at elevated temperatures both in gases and in liquid dielectrics by uniformly distributing throughout the interstices of the insulation certain amounts of one or more of a group of nitrogen-containing nitrile chemical compounds. The amounts of the compounds employed are small, but their presence in the cellulosic insulation imparts greatly improved physical and electrical properties thereto.

The chemical compounds which have been found to impart these improvements are nitrile compounds having the general formula X—R—CN wherein R is a member of the group consisting of alkyl, alkoxy, alkoxy alkane, aromatic, or substituted aromatic substituents, and X is a member of the group consisting of H and —CN. Particularly desirable nitriles are those whose substituents are hydrophilic so that they are soluble in water and relatively insoluble in oil. Dinitriles are exceptionally desirable compounds for this purpose. Representative members of this group of nitrogen-containing, i.e., cyano, compounds include butyl nitrile, octyl nitrile, isooctyl nitrile, adiponitrile, malononitrile, isophthalonitrile, succinonitrile, p-aminobenzonitrile, B-ethoxypropionitrile, and benzylnitrile, as well as the simple substitution derivatives of these compounds for example, alkyl groups on the benzene ring of the aromatic compounds.

It has been discovered that unexpectedly the dielectric strength of paper, or other cellulosic material including gelatinized cellulose or so-called vulcanized hard fiber, treated with one or more of the members of the group of compounds above listed, when immersed in petroleum oil or chlorinated diphenyl dielectric liquid, is not only superior to the same paper in the untreated condition but as the temperature increases, the dielectric strength increases and reaches a peak value at a temperature of from 125° C. to 150° C., or even higher, whereas untreated paper has begun to drop rapidly in dielectric strength at a temperature of from 25° C. to 50° C. lower than that at which the peak dielectric strength of the treated paper occurs.

The power factor of treated cellulosic insulation immersed in liquid dielectrics is lower than that of a similar paper which has not been so treated, over a wide range of temperature aging test conditions. Further, material reductions in power factor occur when the liquid dielectric is oil containing oxidation inhibitors, such as alkylated phenols, for example, p-tertbutylphenol and dibutylparacresol, in amounts of 0.01% to 4% or more since the treated paper appears to be beneficially affected by the presence of such inhibitors. A synergistic cooperative improvement takes place when the nitrile treated paper is in contact therewith since sludging of the oil occurs to a lesser extent while the power factor increases less than when untreated paper is employed therein.

Thus, the power factor of a refined petroleum oil (uninhibited) with kraft paper immersed therein was originally 0.008%, color 1 on the Lovibond scale, after one year at 95° C., the power factor was 0.29% and color was 5+. When the oil was inhibited with untreated kraft paper, the power factor 0.36% and color 5— after one year at 95° C.

With kraft paper treated with the nitriles in accordance with this invention, the color was about 3½ and the power factor of the order of 0.1 to 0.05% after one year at 95° C.

Several factors are involved in obtaining the benefits of the invention. First, the chemical compounds must be present in the cellulosic insulation in total amounts within the range of from about 0.02% to about 10% by weight based on the weight of the cellulosic material. Less than about 0.02% of one or more of the compounds does not impart to the cellulosic insulation any appreciable improvement in either electrical insulation or mechanical strength upon aging at elevated temperatures or upon exposure to elevated temperatures. The presence of more than about 10% of the compound is uneconomical and does not increase the degree of improvement beyond that obtained with 10%. Within this broader critical range, it is preferred to employ about 1% to about 5% by weight of nitrogen-containing compounds, these amounts having been found to impart a high degree of improvement in the electrical insulating and thermal stability properties of the cellulosic insulation.

Second, the stabilizing compound and/or compounds must be present, in substantially uniform distribution, intimately present throughout the interstices of the fibers comprising the cellulosic insulation to obtain optimum benefits. This requirement is readily met because of the fact that all of the members of the group of stabilizing compounds of the invention are readily water soluble and substantially oil insoluble. To maintain the high dielectric properties and mechanical strength it is requisite that the stabilizing compounds be closely associated at all times with the cellulose fibers to obtain the hereinbefore discussed benefits, particularly where the insulation is to be immersed in a liquid dielectric such as oil during use. Where, for example, the stabilizing materials are merely suspended in the dielectric, an extended period of time elapses before the stabilizers permeate the cellulosic insulation and function at maximum effectiveness. This has been the case with urea or like materials previously disclosed in U.S. Patent No. 2,722,561 to McCullough, for example. In fact even where, as McCullough discloses, the stabilizing compounds are applied as dry powders to the insulation as a transformer coil is being wound, the benefits of the present invention are not obtained.

Inasmuch as all of the members of the disclosed group of nitrile stabilizing compounds possess a suitable degree of solubility in water or water-alcohol mixture, they may be desirably applied in such solution to thoroughly permeate the cellulose insulation during its production. In the case of paper or pressboard insulation in particular, incorporation of the compound or compounds may be readily carried out in the paper mill. Paper is generally made on either a Fourdrinier machine or a cylinder type machine. In either method, the formed web of felted cellulosic fibers is transferred from the forming screen to a felt belt for drying. The web is thereby carried through a dryer which consists of a number of steam heated rolls after which, if desired, it is passed between calender rolls to impart a particular surface finish or density, and finally it is rolled for storage and shipment. Also, generally, the dryer is split so that the paper web partially dries in the first portion thereof and is finished dried in the second portion. Between the two sections of heated rolls a tank is usually positioned for application of sizing materials to the paper.

In practicing the present invention, the stabilizing compound or compounds in aqueous solution, are present in and applied from the conventional sizing tank. The partially dried paper is passed through the aqueous nitrile soltuion and, by suitably adjusting the concentration of the solution, it adsorbs a specified amount of stabilizing compound. After this treatment, the paper passes through the second portion of the dryer. The temperature of the drying rolls is determined so as to obtain

sufficient drying and to eliminate later sticking of the treated paper to the calender rolls. The process is applicable equally to either the Fourdrinier or cylinder type paper-making machine.

The resulting dried paper contains the stabilizing compound uniformly and intimately distributed throughout the fiber interstices. Where, as in the case of succinonitrille, the water solubility of the stabilizing compound increases as the temperature of the water increases, it may be desirable to heat the solution and saturate it so that the concentration of succinonitrile is high whereby on passing the paper therethrough a specified high pick-up of the compound is obtained. Usually, temperatures of the order of about 60°–90° C. are adequate.

In order to more fully describe the benefits obtained by practicing the invention, the following illustrative examples are given. In each example, 3% by weight of the particular stabilizing compound was added to kraft paper during its manufacture. In all instances, the paper was 30 mils thick and had a density of approximately 1. Each of the samples of paper was wound with enameled wire into a coil and sealed in a tank filled with transformer oil. Sufficient current was circulated through the coils to generate temperatures of 140° C. The coil unit was removed after seven days and a Mullen's bursting strength test was run on the aged paper in each sample. In Table I, the Mullen bursting strength values are given before and after the tests were run.

Table I

Stabilizing Agent	Mullen Before	Mullen After	Percent Retention
None (100% Kraft)	73	18	24.6
Succinonitrile	52	50	96+
p-Aminobenzonitrile	65	59	91
B-ethoxypropionitrile	61	54	90
B,B[1]-iminodipropionitrile	58	58	100
Diethylaminoacetonitrile	64	55	86
Alpha-hydroxyisobutyronitrile	59	50	85

From the above physical data, it will be seen that whereas the kraft paper containing no stabilizing agent retained only 24.6% of its original bursting strength, the nitrile agents imparted to the treated kraft paper such resistance to aging that the paper retained 85% or more of its original bursting strength. Reference to FIG. 1 which plots the results from other similar tests, will reveal that even after 28 days aging treatment while immersed in oil, the paper treated with succinonitrile retained approximately 80% of its original bursting strength while the untreated kraft paper retained only about 3% thereof.

Tests were made of the dielectric strength of the nitrile treated paper. It will be noted from FIG. 2, which was derived from such dielectric tests, that the nitrile treated kraft papers possess greatly improved dielectric strength retention with increasing temperatures in comparison with an untreated kraft paper.

Using the same treated paper containing about 3% of succinonitrile, a transformer coil was wound in a fashion as illustrated in FIG. 3. The numeral **10** represents the treated kraft paper which is wound around the individual coils and which is wound between the high and low voltage coils of the transformer. Thus, the transformer coil comprises low voltage coils **14** and **16**, as well as high voltage coils **18**, **20** and **22**, insulated by layer-to-layer application of the treated paper. In addition, the low voltage coil **14** is insulated from the treated winding-to-winding by insulation **24**. The electrical conductors employed may comprise enameled wire which resists softening at temperatures of up to 250° C. Suitable enamels are epoxy resin enamels, polyester resin enamels such as isophthalate-glycol-maleate resins, silicone enamels and polyvinyl formal-phenolic resin enamels. The enamels may be applied directly on copper wire or may be employed with asbestos or glass fiber wrapping or other fibrous materials. In the finished transformer, a liquid dielectric will fill the channels 26 and will, as well, completely permeate the paper insulation. Subsequent to being wound and assembled the entire assembly is vacuum treated to remove air and moisture from the paper and the coil is thereafter baked to eliminate fully any moisture.

The nitrile treated insulation of this invention enables the transformer construction to be more solid and tighter because the treated cellulosic spacers and other components lose less than half the thickness loss on thermal aging exhibited by untreated pressboard, kraft paper and other cellulosic materials.

The paper, cloth or other cellulosic product may include small amounts of up to 5% of one or more additional heat and dielectric stabilizing materials such as melamine and dicyandiamide. The cellulosic materials also may include resins or binders such as polyacrylamide resin and melamine-aldehyde resin.

It will be understood that the above description and drawing is only illustrative and not limiting.

I claim as my invention:

1. An improved sheet cellulosic product adapted for use in electrical apparatus in combination with a fluid dielectric impregnant, the product comprising cellulosic fibers in sheet form, the sheet having uniformly distributed throughout its interstices from about 0.02% to about 10% by weight based on the weight of the cellulosic fibers of a nitrile compound having the general formula

X—R—CN

wherein R is a member of the group consisting of alkyl, alkoxy, alkoxy alkane, aromatic, and substituted aromatic substituents, and X is a member of the group consisting of H and —CN.

2. The cellulosic product of claim 1 wherein the nitrile comprises a dinitrile.

3. The cellulosic product of claim 1 wherein the nitrile compound is succinonitrile.

4. The cellulosic product of claim 1 wherein the nitrile compound is B,B′-iminodipropionitrile.

5. The cellulosic product of claim 1 wherein the nitrile compound is B, ethoxypropionitrile.

6. In improved electrical apparatus comprising, in combination, an electrical conductor winding provided with a hard, tough, flexible enamel coating which resists softening at temperatures up to about 250° C., cellulosic electrical insulation substantially around the winding, the improvement which comprises the provision of from 0.02% to 10% by weight, based on the total weight of the cellulosic electrical insulation of at least one nitrile compound having the general formula

X—R—CN

wherein R is a member of the group consisting of alkyl, alkoxy, alkoxy alkane, aromatic, and substituted aromatic substituents, and X is a member of the group consisting of H and —CN, said nitrile compound being uniformly distributed throughout the interstices within the cellulosic electrical insulation, and a liquid dielectric consisting essentially of a petroleum hydrocarbon oil surrounding at least part of said electrical conductor winding and substantially completely permeating said cellulosic electrical insulation.

7. In electrical apparatus comprising an electrical conductor developing heat when in operation, cellulosic insulation applied to the conductor, a fluid dielectric applied to the electrical conductor to provide for heat dissipation and electrical insulation, the improvement which comprises an additive to improve the electrical properties of the cellulosic insulation and to increase the thermal stability of the cellulosic insulation, the said additive distributed within the cellulosic insulation and comprising from about 0.02% to about 10% by weight based on the weight of the cellulosic fibers of a nitrile compound having the general formula

X—R—CN

wherein R is a member of the group consisting of alkyl, alkoxy, alkoxy alkane, aromatic, and substituted aromatic substituents, and X is a member of the group consisting of H and —CN.

8. Electrical apparatus as in claim 7 wherein the nitrile compound is succinonitrile.

9. The electrical apparatus as in claim 7 but wherein the nitrile compound is B,B′-iminodipropionitrile.

10. The electrical apparatus as in claim 7 but wherein the nitrile compound is B, ethoxypropionitrile.

11. In improved electrical apparatus comprising, in combination, an electrical conductor winding provided with a hard, tough, flexible enamel coating which resists softening at temperatures up to about 250° C., and cellulosic electrical insulation substantially around the winding, the improvement which comprises the inclusion of from 0.02% to 10% by weight, based on the total weight of the cellulosic electrical insulation of at least one nitrile compound having the general formula

X—R—CN

wherein R is a member of the group consisting of alkyl, alkoxy, alkoxy alkane, aromatic, and substituted aromatic substituents, and X is a member of the group consisting of H and —CN, said nitrile compound being uniformly distributed throughout the interstices within the cellulosic electrical insulation, and a liquid dielectric consisting essentially of a petroleum hydrocarbon oil surrounding at least part of said electrical conductor winding and substantially completely permeating said cellulosic electrical insulation, and an inhibitor in the petroleum oil in an amount of at least 0.01% by weight, the whole cooperating to produce less sludge and less increase in power factor with use as compared to the same apparatus with cellulosic insulation containing no additive.

12. In improved electrical apparatus comprising, in combination, an electrical conductor winding provided with a hard, tough, flexible enamel coating which resists softening at temperatures up to about 250° C., and cellulosic electrical insulation substantially around the winding, the improvement which comprises the inclusion of from 0.02% to 10% by weight, based on the total weight of the cellulosic electrical insulation of at least one nitrile compound having the general formula

X—R—CN

wherein R is a member of the group consisting of alkyl, alkoxy, alkoxy alkane, aromatic, and substituted aromatic substituents, and X is a member of the group consisting of H and —CN, said nitrile compound being uniformly distributed throughout the interstices within the cellulosic electrical insulation, and a liquid dielectric consisting essentially of chlorinated diphenyl surrounding at least part of said electrical conductor winding and substantially completely permeating said cellulosic electrical insulation.

References Cited in the file of this patent

UNITED STATES PATENTS

2,722,561	McCulloch	Nov. 1, 1955
2,901,813	Schappel	Sept. 1, 1959