

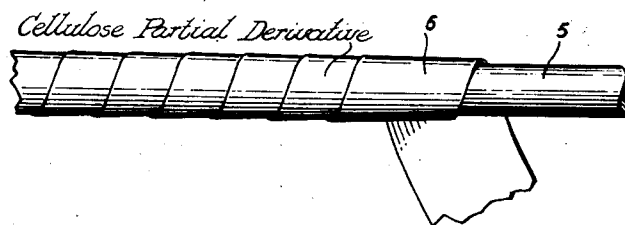
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CONDUCTOR INSULATED WITH CELLULOSE MATERIAL

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CONDUCTOR INSULATED WITH CELLULOSE MATERIAL

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This invention relates to insulated electric conductors and to insulation for similar purposes wherein the basis of the insulating material is cellulose.

5 It is well known that the insulation value of cellulosic materials is largely governed by the quantity of moisture and ionizable material associated with the cellulose micelles or fibres under operating conditions of humidity. When the latter is high, the cellulose insulations at present
10 in use are unsatisfactory, and in order to overcome these undesirable properties several attempts have been made to treat the cellulosic material by some such process as careful washing.
15 Although these processes are known to reduce the quantity of ionizable constituents present with a corresponding slight decrease in water absorptive properties and improvement in insulation value, the gain is not sufficient for all
20 types of insulation and further improvement is desirable.

An object of this invention is to produce a conductor electrically insulated with a material exhibiting the fibrous structure and consequent
25 mechanical strength typical of cellulosic bodies which have reduced moisture absorption and improved insulation value.

According to one feature of the present invention, a conductor is insulated with a cellulosic
30 fibrous material in the form of yarn, woven fabric, paper, twine or disintegrated fibres subsequently formed into yarn, fabric, paper, twine, etc., which has been subjected to a reagent or
35 mixture of reagents which gradually convert the cellulose into esters or ethers, the process being conducted for a period of time depending on the particular reagent or mixture of reagents employed and the temperature, and determined
40 by the electrical characteristics of the product after washing and drying, in such a way that the insulation resistance of the product is greater than the insulation resistance of the untreated material or the untreated material which has
45 merely been subjected to a careful washing process without any chemical change in the structure of the cellulose when tested under identical conditions of humidity, temperature, etc., the reagent or mixture of reagents having this characteristic, that during the time of treatment as
50 above determined, they do not markedly alter the mechanical or physical structure of the fibres or do not markedly reduce their mechanical strength. Thus, the process may in practice be

determined as regards reagents and time on a test sample giving an insulation resistance of a $\frac{1}{2}$ " length of the material greater than 10⁶ megohms per gm. at 70% relative humidity and temperature of 40° C. Alternatively, the process
5 may be determined as regards said factors as giving a test sample whose moisture absorption is less than 4% by weight in the case of textiles and 6% by weight in the case of papers at 70%
10 relative humidity and a temperature of 20° C., the dry weight basis being taken after desiccating for 48 hours over phosphorous pentoxide in vacuum.

The nature of these and other features of the invention will be more readily understood from
15 the following description of examples of carrying out the invention and the accompanying drawing, the single figure of which illustrates one embodiment of the invention wherein an
20 individual conductor is insulated with a layer of paper which has been partially esterified or etherified. In accordance with this drawing the conductor 5 is provided with a layer of paper
25 6 which has been treated with suitable reagents and in such a way as to convert the cellulose fibers of the paper into partial esters or ethers without materially altering their mechanical structure.

In preparing the insulating paper 6 it has
30 been found preferable to convert the cellulose fibers into a partial ester, such as the mono-acetate or di-acetate in which case cotton yarn in a suitable form such as that of loose cops
35 or hanks is immersed in a well stirred bath comprising acetic anhydride, a dehydrating catalyst and glacial acetic acid as a diluent for a time sufficient to convert the cellulose present into a
40 partially acetylated derivative showing on analysis an acetic acid content equivalent to approximately the mono-acetate (29.4% by weight) after which the esterified product is carefully washed
45 with water until all traces of the reagents have disappeared.

An acetylating bath in which the proportions are 20% acetic anhydride, 10% anhydrous zinc chloride and 70% glacial acetic acid (% by weight) has been found suitable and takes about
50 20 hours to convert the fibres to the mono-acetate at 40° C.

A sample of the product was found to have a moisture absorption of less than 4% when dried out for 48 hours in vacuum over phosphorous
55

pentoxide and then placed in an atmosphere of 70% relative humidity at 20° C.

A further sample of the product $\frac{5}{8}$ " long, weighing one gram, when tested after washing and drying at a temperature of 40° C. and at a 70% relative humidity shows an insulation resistance of at least 10^5 megohms.

By increasing the temperature of the bath the time required to carry the acetylation to the desired stage is reduced, so that at 80° C., under one hour would be required, using the bath described above. It is, however, not advisable to use too high a temperature, as this results in uneven acetylation, increased loss of material due to the formation of cellulose tri-acetate which is soluble in the bath and destruction of the form and structure of the yarn.

Certain other partial cellulose esters and ethers yield suitable products such as methyl, ethyl and phenyl cellulose. In each case the cellulose is reacted upon by an oxygenated organic compound in such a way as to form the corresponding derivative and the reaction is not allowed to proceed to the stage where the mechanical structure of the cellulose fibers is materially altered. In the formation of the ester, the cellulose fibers may be reacted upon, for example, by an acid anhydride or an acid chloride. In the formation of the ether the cellulose fibers may be reacted upon by an acyl or alkyl halide in such a way as to form the corresponding ether.

In general, the known method of preparing the fully esterified or etherified product is adopted and moderated by reducing the concentration of the active reagents or by reducing the temperature of the reaction (in a similar manner to that described above for the acetylation) whereby the cellulosic material can be removed at the desired stage equivalent to the formation of a partial ester or ether with the required characteristics of mechanical strength, fibrous structure, moisture absorption and insulation value cited already.

It should be understood that in the acetylation of cellulose, this invention is not limited to the above typical bath composition but that the proportions of the constituents can be varied between quite wide limits and still yield satisfactory results, provided the other variables, i. e., time of acetylation, temperature of acetylation, type of catalyst, etc., are carefully chosen.

For most purposes the acetylation is stopped approximately at the mono-acetate stage (i. e. an acetic acid content by analysis of 29.4% by weight). From experimental curves it is possible to gauge the time necessary to complete the reaction to this stage. The mono-acetate is preferred because this shows the optimum conditions of mechanical strength and moisture absorption reduction and electrical insulation value.

The fact that the mono- and di-acetates of cellulose cannot be separated in the pure state (the terms mono- and di-acetate referring in this specification to the mean analytical value) it is apparent that all degrees of acetylation from zero to that equivalent to the tri-acetate can be obtained. For certain purposes it may be desirable to increase the acetic acid content to a value beyond that equivalent to the mono-acetate, i. e. up to 48.8% which is equivalent to the di-acetate, this is accomplished by a longer period of acetylation.

In order to conserve the acetic anhydride re-

agent, it is usual in practice to have present only a slight excess beyond the theoretical quantity for the particular acetate required, thus theoretically 62.9 grams are required to transform 100 grams of cellulose in 125.9 grams of cellulose mono-acetate and a proportionately larger quantity for the di-acetate. Usually 80-100 grams would be employed in the former instance, to allow for that decomposed by the water present in the fibres and that lost by the formation of small quantities of cellulose tri-acetate.

It is obvious that by limiting the quantity of acetic anhydride that the reaction may be stopped at any desired stage.

In order to obtain uniform acetylation, it is sometimes desirable to pre-treat the cellulose fibres to remove all traces of fatty or waxy matter and nitrogenous compounds. In the case of cotton yarn this is readily achieved by Kier boiling, i. e. boiling with 2% caustic soda solution in the absence of air under three atmospheres pressure, followed by thorough washing. Other well known methods may be used and prove equally satisfactory.

Dehydrating catalysts hitherto employed for the preparation of cellulose tri-acetate may be used to accelerate the esterification provided that the quantity of the more strongly acting types is reduced to permit even acetylation of the fibres.

Homogeneous partial acetylation of cellulose fibres may be carried out equally well in two stages, so that the cellulose material is first treated with one or two of the constituents of the acetylating mixture, the remaining constituent or constituents being subsequently added.

In practice the theoretical yield of cellulose mono- or di-acetate is never realized owing to a slight loss occurring due to the formation of traces of cellulose tri-acetate which are soluble in the bath, this only becomes pronounced if acetylation is continued beyond the mono-acetate stage. It is advantageous in that it ensures that no tri-acetate is present in the product.

The acetylating bath may be used repeatedly provided deficiencies of acetic anhydride and dehydrating catalyst are made good.

The following figures for the moisture absorption of partially acetylated cotton were obtained on samples of 2/30s washed and purified cotton acetylated in the bath of composition already described at 20° C.

For comparison figures for several other commercial cottons and acetate silks are included, together with samples of partially acetylated cottons acetylated in baths of different compositions.

Sample	Time of acetylation in hours	Percent combined acetic acid content	Percent moisture absorption at a relative humidity of —				
			25.5%	50%	70.8%	88.8%	100%
2/30s washed and purified cotton partially acetylated.	14½	0	3.24	5.27	7.42	11.11	15.24
	22½	5	2.81	5.01	7.40	10.26	13.66
	38½	10.0	2.29	4.41	6.39	8.61	12.05
	62	18.4	2.06	3.57	5.30	7.83	10.86
	86	25.8	1.46	2.86	4.65	6.95	9.61
	134½	38.3	1.06	2.28	3.92	6.11	8.77
	182½	45.6	1.05	2.28	3.85	6.28	8.64
Partially acetylated 2/30s cotton.	-----	29.14	1.05	2.21	3.75	5.87	7.99
	-----	29.58	0.95	2.09	3.51	5.53	6.97
Partially acetylated 2/26s cotton.	-----	28.0	1.08	2.20	3.73	6.00	8.23

Sample	Time of acetylation in hours	Percent combined acetic acid content	Percent moisture absorption at a relative humidity of —				
			25. 5%	50%	70. 8%	88. 8%	100%
5							
Partially acetylated cotton tape.	-----	29. 51	0. 86	2. 06	3. 55	5. 91	8. 18
10							
Commercial cellulose acetate silks.	-----	51. 75	1. 53	3. 63	5. 69	8. 45	11. 55
	-----		1. 81	4. 05	6. 98	10. 49	14. 58
	-----		1. 49	3. 39	5. 51	8. 48	11. 49
	-----		1. 54	3. 49	6. 20	9. 55	14. 42
2/30s cotton yarn samples.	-----		2. 96	5. 19	7. 57	11. 33	15. 28
	-----		2. 85	5. 19	7. 25	9. 54	12. 69
15							
2/30s washed cotton yarn samples.	-----		3. 01	5. 09	7. 33	9. 71	14. 30
	-----		3. 04	5. 32	7. 51	9. 81	13. 05
2/30s washed and purified cotton yarn.	-----		2. 90	4. 92	7. 06	10. 74	14. 86
20							

The following figures for the insulation resistance and mechanical strength of 2/30s cotton treated after the manner described therein further illustrate the invention:—

Insulation resistance per gram of textile measured on a $\frac{5}{8}$ " length thread with an applied voltage of 96 volts D. C.

Temperature °C.	Textile	Relative humidity					
		40%	50%	60%	70%	80%	90%
25° C.	Partially acetylated cotton (2/30s) (29.58% combined acetic acid)	X	X				
		150,000,000	45,000,000	12,000,000	2,800,000	560,000	70,000
	Cellulose acetate silk	2,000,000	1,400,000	800,000	500,000	220,000	50,000
40° C.	Untreated cotton	3,200	800	160	28	5.0	0.7
	Partially acetylated cotton (2/30s) (29.58% combined acetic acid)	X	X	X			
		400,000,000	56,000,000	28,000,000	7,000,000	1,580,000	310,000
	Cellulose acetate silk	800,000	560,000	380,000	250,000	120,000	50,000
	Untreated cotton yarn (2/30s)	800	225	63	16	3.9	0.7

X. These figures were obtained by extrapolation as the actual measurements were beyond the sensitivity of the measuring instruments.

Tensile strength measured on 18" length at a relative humidity of 70%

Textile	Mean breaking load	Mean elongation at break
Partially acetylated 2/30s cotton (29.50% combined acetic acid)	Ounces 15.3	Percent 5.0
Untreated 2/30s cotton	14.6	5.9

Conductors insulated with material herein described are particularly suitable for use in humid atmospheres. Where paper is treated in accordance with the above methods it may be used for cable insulation in the manner disclosed in the

drawing or for the dielectric for condensers and for similar purposes.

In the paper esterified in the above described manner the strength and structural desiderata will be retained but the affinity for moisture due to exposed cellulose surface will be reduced considerably. Thus, in either unimpregnated or impregnated conditions the insulating qualities of the paper will be considerably improved.

Moreover, owing to the changes in fibre bulk during esterification and owing to the reduced specific inductive capacity of cellulose esters compared with pure cellulose, it should be possible to control the impregnated and unimpregnated characteristics (dielectric) of the paper during esterification to a degree that cannot be attained during the manufacture of the paper itself.

What is claimed is:

1. An electric conductor comprising a conducting core and a layer of paper surrounding said core, said paper consisting of cellulose fibers which have been converted into partial ethers without materially affecting their mechanical structure.

2. An electric conductor comprising a conducting core and a layer of paper surrounding said core, said paper consisting of partially etherified cellulose fibers having substantially the same mechanical structure as the original cellulose fibers and selected from the group which consists of methyl cellulose, ethyl cellulose and phenyl cellulose.

3. An electric conductor comprising a conducting core and a layer of paper surrounding said core, said paper consisting of partially etherified methyl cellulose in which the mechanical structure of the original cellulose fibers is substantially retained.

4. An electric conductor comprising a conducting core and a layer of paper surrounding

said core, said paper consisting of partially etherified ethyl cellulose in which the mechanical structure of the original cellulose fibers is substantially retained.

- 5 5. An electrical conductor comprising a conducting core and a layer of paper surrounding

said core, said paper consisting of partially etherified phenyl cellulose in which the mechanical structure of the original cellulose fibers is substantially retained.

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