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PAPER FOR USE IN THE MANUFACTURE OF ELECTRIC CABLES AND CAPACITORS AND OTHER PURPOSES

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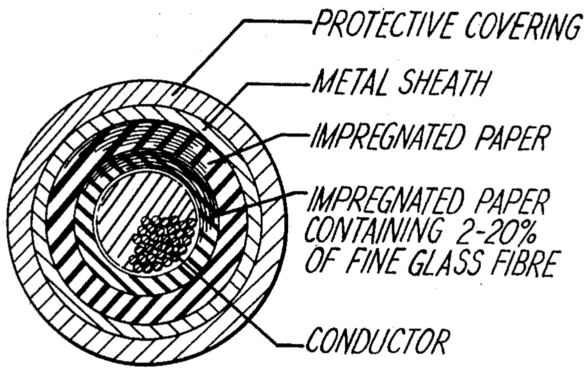

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PAPER FOR USE IN THE MANUFACTURE OF ELECTRIC CABLES AND CAPACITORS AND OTHER PURPOSES

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This invention is concerned with paper for use, after impregnation with an insulating oil or compound, as dielectric material. More especially it is concerned with paper for use in the manufacture of impregnated-paper-insulated electric cables.

Paper is a felted fabric of vegetable fibres which for insulating purposes must usually have a high tensile strength to enable it to be lapped or wound at high speed without breakage and, for cable manufacture, must have good resistance to tearing and freedom from brittleness to permit the finished cable to be bent without damaging the paper of which the cable dielectric is built up. It should also have a high electrical breakdown strength, a low power factor and be of uniform thickness and density and capable of being uniformly impregnated with insulating oil or compound. Although capacitor tissue of a thickness of 1 mil or less is available which has been impregnated an electrical impulse breakdown strength of about 3000 kv./cm., when tested in single-sheet form, it has not hitherto been possible to manufacture cable insulating paper having an equivalent impulse breakdown strength but which has a thickness of 2 mils or more, the best 3 mil cable paper at present in use having a single sheet, impulse breakdown strength of little more than 2000 kv./cm.

I have now found that a paper that meets all resonable requirements of the cable maker as regards mechanical strength, absence of brittleness, uniformity of thickness and density and impregnability, and low power factor yet has an unexpectedly high electrical breakdown strength which approximates to that of the best capacitor tissue can be obtained from an extremely well-beaten wood pulp stock, capable of yielding a very high impermeability paper, in which stock is incorporated from 2 to 20%, preferably from 5 to 10%, of very fine glass fibre.

The proportion of glass fibre to yield a paper having optimum breakdown strength appears to be about 8%. Between 0 and 5% the breakdown strength increases uniformly with the increase in glass fibre content, above 5% it increases less rapidly to a maximum of about 8% and then decreases at about the same rate until the content reaches about 10%. Further increase up to 20% in glass fibre content results in a substantially uniform decrease in breakdown strength but at a rate less steep than the rate of increase over the range 0% to 5% of glass fibre content.

The size of the glass fibre appears to be critical. High breakdown strength is obtainable only with very fine glass fibre, that is to say, fibre having a diameter of one micron or less. It should also be short, for example, of an average length of about 0.1 mm. Fibre of this diameter is known in U.S.A. as "AAA grade." The incorporation in wood pulp of glass fibre obtained by treating ordinary glass wool having a fibre diameter of about 0.017 mm. in a beater fails to give a similar increase in the breakdown strength of the paper manufactured from it and results in a brittle sheet. To obtain the low power factor required of a cable dielectric, I prefer to use an alkali-free or low alkali content glass fibre, for example, glass fibre known in the U.S.A. as "type E."

The degree to which the wood pulp is beaten is also of great importance. I have found that this should be

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extremely well-beaten in order to obtain an increase in the breakdown strength by the incorporation of very fine glass fibre. By "extremely well beaten" I mean having a Schopper-Riegler (freeness) value closely approaching or equal to 90°, or even higher. The addition of such fibre to pulps having a substantially lower freeness value, e.g. a value of from 40° to 65° S.R. such as those normally used for the manufacture of cable paper, was found not to raise but to lower the breakdown strength of the paper. I prefer to use an unbleached, water-washed sulphate pulp, preferably of first quality.

The paper made in accordance with the invention can be used in the manufacture of impregnated paper insulated electric cables by conventional methods.

Examples of the manufacture of paper in accordance with the invention will hereinafter be described.

In all cases the glass fibre used was of alkali free borosilicate glass (known as "type E" in U.S.A.) and of a diameter corresponding to that known as "grade AAA" in U.S.A. The pulp used was a first quality, unbleached, water-washed, sulphate wood pulp. The wood pulp was beaten until it had a Schopper-Riegler freeness value as indicated in the second column of the table below and the glass fibre, dispersed in low conductivity (demineralised) water, was then mixed with the wood pulp in the beater, 5% by weight (based on the glass fibre) of a water soluble methyl ether of cellulose, having a viscosity of 20 centipoises at 20° C. in 2% aqueous solution, being added to the suspension of glass fibres as deflocculating agent.

My preferred method of making a single and double ply papers in accordance with the invention from the pulp containing glass fibre thus obtained is as follows. After mixing the glass fibre with the pulp in the beater the mixture was diluted to .5% solids in the stock chest of the papermaking machine (again using low conductivity water) and diluted to 0.3% solids in the breast box of the machine prior to sheet formation on the Fourdrinier wire.

The single ply papers were made directly on the machine by the normal process. Although I would normally prefer to make the two ply papers on a twin wire machine, in this case they were made on a single wire machine by taking from the machine a wet web of paper on to a roll and later combining it with a web of paper passing through the machine at the first press.

Details of single ply and double ply paper made in this way are set out as Examples 1, 2 and 3 in columns (3)–(8) of the table below.

The "substance" (column 5) was obtained by weighing squares 5 x 5 cms. on an analytical balance. The thickness was obtained by taking five readings on each square with a standard paper-makers' dead-weight micrometer and the density was calculated from substance and thickness. The mechanical properties of the papers were found to be comparable with those of good quality cable paper.

For comparison purposes similar single and double ply papers were made in exactly the same way except that the glass fibre was omitted. Details of these papers are shown as Examples 4 and 5 respectively in the table below.

Samples of all five papers were vacuum dried and impregnated with a light mineral oil of the kind used in oil filled cables, the oil being a naphthenic-base oil with a high proportion of aromatics derived from low sulphur, low-wax crude oils of South American origin, subjected after distillation to 95% acid and clay treatment and having a viscosity at 25° C. of 25 centistokes. The impulse strength of all of the impregnated papers was measured on single layers of the paper from each batch using ⅛" diameter electrodes, the sample being immersed in the impregnant. The impulse strength was calculated on the thickness of the impregnated paper. From column (9) of the table below it will be seen that the addition of 5% by weight of the glass fibre to a single ply paper of thickness about 3 mils, made from the extremely well beaten pulp, gives an increase in impulse strength of 14% and that for similar paper in two ply form the addition of 5% of the glass fibre gives an increase of 31% and of 7½% of the glass fibre an increase of 62%.

To show the effect of varying the beating time and varying the glass fibre content, comparative tests were carried out on papers made on a laboratory sheet making apparatus from the same glass fibre and wood pulp as used in Examples 1–5. The same impregnant was used and the impulse strength was measured under the same conditions. The results obtained are set out in the table below as Examples 6–15.

Table

(1) Example	(2) Freeness	(3) Percent Glass	(4) No. of plies	(5) Substance (g/m^2)	(6) Thickness (Mil)	(7) Density (g/cm^3)	(8) Impermeability (Gurley Sec/mil)	(9) Impulse Strength (kv./cm.)
1	90	5	1	81	3.10	1.03	45,000	1,830
2	90	5	2	69	2.50	1.09	240,000	2,240
3	87	7½	2	90	3.29	1.08	9,000	2,770
4	90	0	1	70	2.52	1.10	150,000	1,600
5	90	0	2	75	2.96	1.00	280,000	1,710
6	93	0	1	100	3.5	1.14	400,000	1,830
7	93	5	1	84	2.9	1.14	160,000	3,040
8	93	10	1	89	3.0	1.19	20,000	3,040
9	93	20	1	93	3.0	1.21	5,000	3,020
10	93	40	1	83	3.0	1.09	500	2,450
11	93	40	1	80	2.9	1.08	80	1,870
12	93	80	1	77	2.8	1.08	20	------
13	65	0	1	83	3.1	1.05	800	2,100
14	65	5	1	84	3.2	1.04	400	1,980
15	65	10	1	85	2.2	1.05	200	1,940

It will be seen from Examples 6 to 15 that the highest impulse strengths were obtained when the freeness value was 93 and the glass fibre content from 5–20%.

The accompanying drawing shows in cross-section an impregnated paper insulated power cable in which the inner part of the dielectric is of the paper referred to as Example 3 and the outer part is of a standard cable paper.

What I claim as my invention is:

1. An impregnated paper insulated cable comprising at least one conductor, impregnated dielectric material surrounding said conductor, and an impervious sheath surrounding said dielectric material, in which at least a part of the impregnated dielectric material comprises paper made from an extremely well beaten wood pulp stock containing from 2% to not more than 20% by weight of short glass fibre of a diameter not greater than one micron impregnated with an impregnant selected from the group consisting of mineral insulating oils and compounds based on such insulating oils.

2. A cable in accordance with claim 1 in which the content of the glass fibre in the stock is 5–10%.

3. An impregnated paper insulated cable in accordance with claim 1 in which the wood pulp stock is beaten to a Schopper-Riegler freeness value at least closely approaching 90°.

4. An impregnated paper insulated cable comprising at least one conductor, impregnated dielectric material surrounding said conductor, and an impervious sheath surrounding said dielectric material, in which at least a part of the impregnated dielectric material comprises paper made from an extremely well beaten unbleached, water-washed, sulphate wood pulp stock containing from 2% to not more than 20% by weight of short, low alkali content borosilicate glass fibre of a diameter not greater than one micron, impregnated with an impregnant selected from the group consisting of mineral insulating oils and compounds based on such insulating oils.

5. A cable in accordance with claim 4 in which the content of the glass fibre in the stock is 5–10%.

6. An impregnated paper insulated cable in accordance with claim 4 in which the wood pulp stock is beaten to a Schopper-Riegler freeness value at least closely approaching 90°.

7. An impregnated paper insulated cable comprising at least one conductor, impregnated dielectric material surrounding said conductor, and an impervious sheath surrounding said dielectric material, in which the inner part of the impregnated dielectric material comprises paper made from an extremely well beaten wood pulp stock containing from 2% to not more than 20% by weight of short glass fibre of a diameter not greater than one micron impregnated with an impregnant selected from the group consisting of mineral insulating oils and compounds based on such insulating oils and the outer part of the impregnated dielectric material comprises paper not containing glass fibres impregnated with the same impregnant.

8. An impregnated paper insulated cable comprising at least one conductor, impregnated dielectric material surrounding said conductor, and an impervious sheath surrounding said dielectric material, in which the inner part of the impregnated dielectric material comprises paper made from an extremely well beaten unbleached, water-washed, sulphate wood pulp stock containing from 2% to not more than 20% by weight of short, low alkali content borosilicate glass fibre of a diameter not greater than one micron, impregnated with an impregnant selected from the group consisting of mineral insulating oils and compounds based on such insulating oils and the outer part of the impregnated dielectric material comprises paper not containing glass fibres impregnated with the same impregnant.

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