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Matsuda et al.

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[45] **Nov. 27, 1973**

[54] **ELECTRICALLY INSULATING POLYPROPLYENE LAMINATE PAPER AND OIL-IMPREGNATED ELECTRIC POWER CABLE USING SAID LAMINATE PAPER**

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July 8, 1971 Japan 46/50572

[52] **U.S. Cl.** .... **174/25 R,** 156/278, 156/292, 161/250, 174/110 PM, 174/120 FD, 174/120 SR

[51] **Int. Cl.** ... **H01b 9/06,** B32b 27/10, B32b 31/12

[58] **Field of Search** .... 174/25 R, 25 C, 23 R, 174/110 PM, 120 R, 120 FP, 120 SR; 161/250, 252, 402; 162/123, 125, 132, 157; 156/313, 325, 327, 292, 278

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[57] **ABSTRACT**

An insulation for electric cables which comprises a biaxially oriented polypropylene film bonded to an oil-impregnated paper by means of a melt-extruded polyolefin adhesive and the resulting insulated cable are disclosed.

12 Claims, 7 Drawing Figures

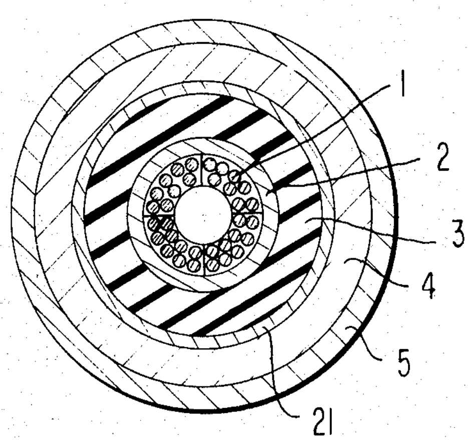
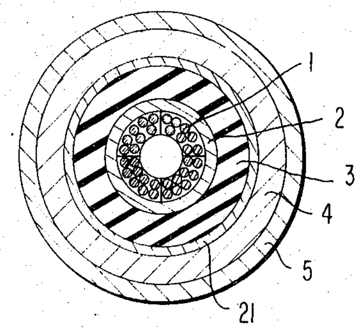
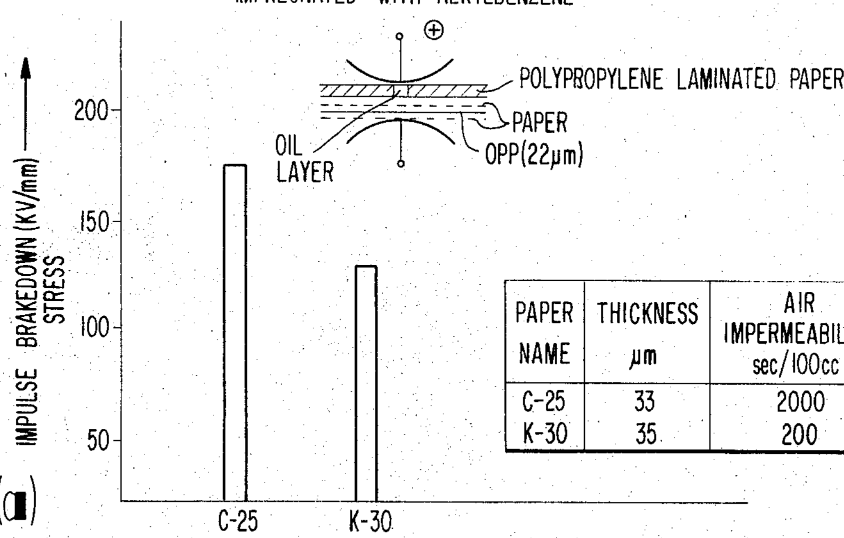


FIG 1





PAPER NAME	THICKNESS μm	AIR IMPERMEABILITY sec/100cc
C-25	33	2000
K-30	35	200

FIG 2(a)

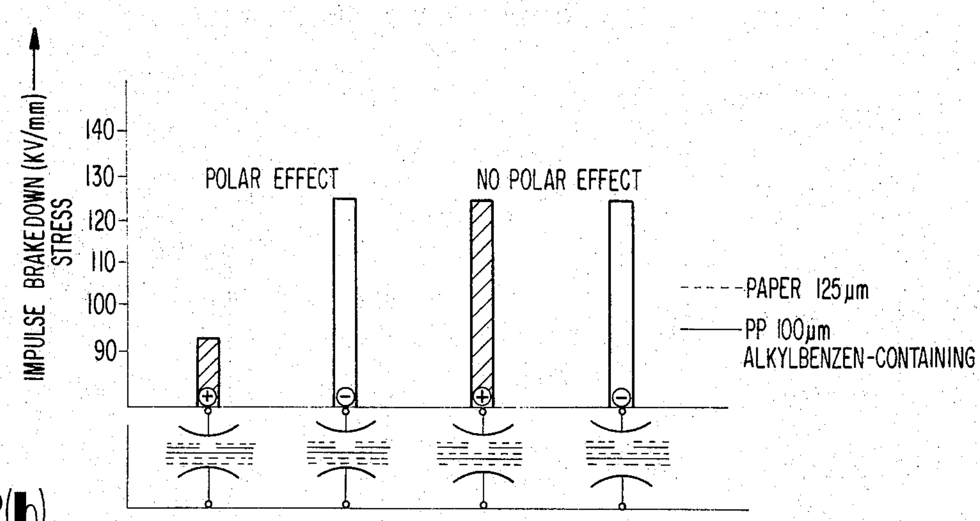


FIG 2(b)

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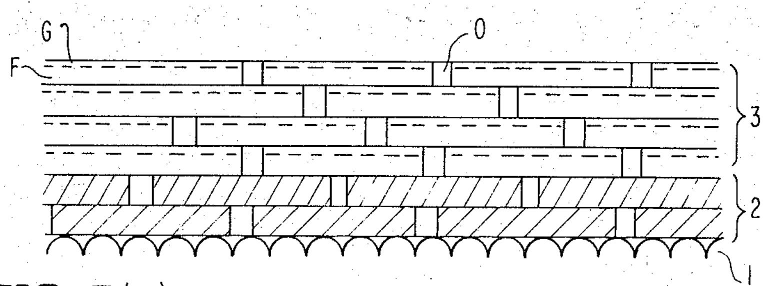


FIG. 3(a)

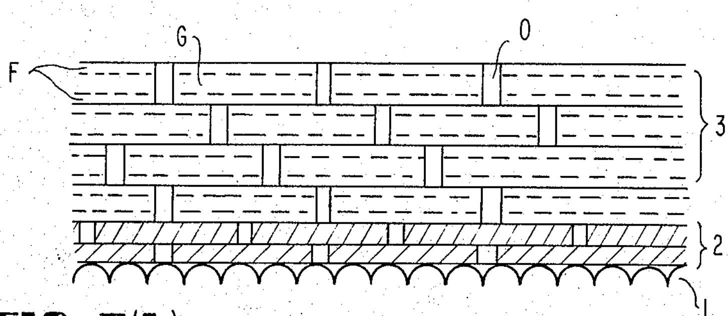
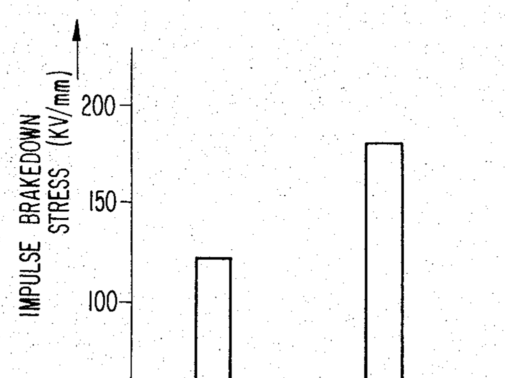


FIG. 3(b)



SAMPLE	CONVENTIONAL OF CABLE MODEL INSULATED CELL-OSE PAPER TAPES	CABLE MODEL OF THIS INVENTION
POLARITY AND TEMPERATURE	⊕ ⊖ 80°C	⊕ ⊖ 80°C
$\varepsilon_s/\varepsilon_l$	1.7	1.2

OIL PRESSURE	1 Kg/cm^2
CABLE MODEL LENGTH	2m
INSULATION THICKNESS	2mm
TAPE WIDTH	19mm

FIG. 4

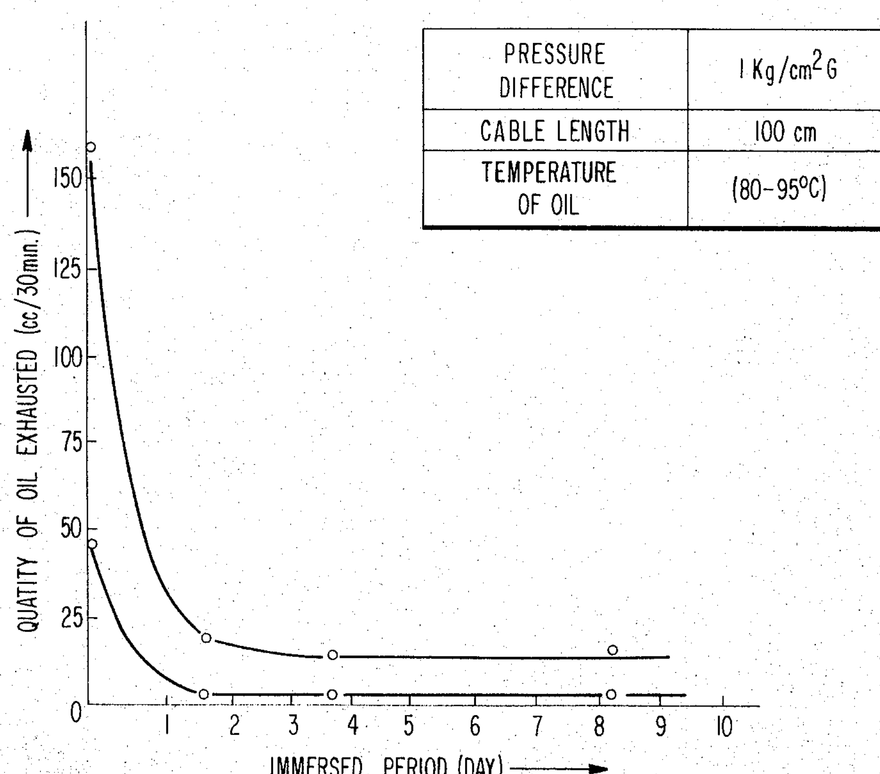

PRESSURE DIFFERENCE
1 Kg/cm2 G
CABLE LENGTH
100 cm
TEMPERATURE OF OIL
(80-95°C)
QUATITY OF OIL EXHAUSTED (cc/30min.)
150
125
100
75
50
25
0
1
2
3
4
5
6
7
8
9
10
IMMERSED PERIOD (DAY)

FIG. 5

ELECTRICALLY INSULATING POLYPROPLYENE LAMINATE PAPER AND OIL-IMPREGNATED ELECTRIC POWER CABLE USING SAID LAMINATE PAPER

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates to an electrically insulating polypropylene laminate paper for use in oil-impregnated insulated electric machinery and gas-filled insulated machinery, such as electric power cables, electric power capacitors or transformers, and to an oil-impregnated electric power cable using said laminate paper.

DESCRIPTION OF THE PRIOR ART

In recent years, electric machinery such as oil-impregnated electric cables as a typical example which withstand extra high voltages have been developed, and on the other hand, for the purpose of reducing the cost, there is a tendency towards the production of smaller size electric machinery. Therefore, solid insulating material for use in such electric machinery, especially, electrically insulating tapes, require superior dielectric characteristics such as dielectric loss tangent (tan δ) or dielectric breakdown strength against impulse voltage or A.C. voltage, and also superior mechanical strength and operability.

Attempts have been made to use plastic films having low tan δ as such an electrically insulating tape, instead of the conventional electrically insulating paper. The plastic films have very good initial impulse strength dielectric characteristics, but have the defect that they are drastically deteriorated in resistances to repeated application of impulse voltage or to AC voltage for prolonged periods of time. In addition, they have the temperature dependent characteristics inherent in plastic films or have large polar effects on impulse voltage. As further disadvantages, the plastic films have poor working efficiency, for example in tape winding operations, because of lack of rigidity, and the packing action inherent in the plastic films makes it difficult to dry electric cables or other electric machinery under vacuum which in turn leads to poor flowability of insulating gases or oils.

On the other hand, oil-impregnated paper has inferior dielectric characteristics or electric breakdown strength compared to the plastic films, but is superior in other respects. However, the tan δ of oil-impregnated paper is considered to be 0.1 percent at the lowest, and temperature rise due to tan δ loss exerts limitations on the application of electric cables or other equipment to extrahigh voltage and on the reduction in size of such electric equipment.

A system has been devised which consists of alternate winding of the above-described plastic film and oil-impregnated paper in an attempt to utilize the merits of these two materials. However, when this system is so arranged that the plastic film faces the conductor, it is weak to positively polar impulses. In order to avoid this, the electrically insulating paper may be first wound facing the conductor and then the plastic film is wound thereon, in the case of transformers or capacitors. With electric cables, a larger proportion of the plastic film faces the conductor side in an oil layer and the defect of weakness to positively polar impulses is not eliminated. In this alternately wound system, too, the plastic film of small rigidity needs to be wound alone, and therefore, improvement in working efficiency can hardly be hoped for.

SUMMARY OF THE INVENTION

The present invention has eliminated the above-mentioned defects, and its first feature is to provide an electrically insulating polypropylene laminate paper comprising an integrated assembly of a biaxially stretched polypropylene film and an electrically insulating paper bonded to each other through the medium of a molten polyolefin such as polypropylene or an ethylene/propylene copolymer.

A second feature of this invention is to provide an electric cable wherein a tape of the above-mentioned electrically insulating polypropylene laminate paper is wound on an electric conductor to form insulation layers, and an insulation oil is impregnated therein.

A third feature of this invention is to provide an electric cable impregnated with an electrically insulating oil by winding the electrically insulating polypropylene laminate on a conductor while the electrically insulating paper is being rendered wet, and then drying it to remove moisture, which process is based on the utilization of the moisture absorbing characteristics of the electrically insulating paper.

BRIEF DESCRIPTION OF THE DRAWINGS:

FIG. 1 is a sectional view of a single-core OF cable of the present invention.

FIGS. 2(*a*) and 2(*b*) show the results of an impulse breakdown test on a sheet impregnated with an alkylbenzene oil.

FIGS. 3(*a*) and 3(*b*) are enlarged sectional views of the insulating layer(s) of the present invention.

FIG. 4 shows the result of an impulse breakdown test on an OF paper-polypropylene sheet impregnated with an alkylbenzene oil.

FIG. 5 shows the variation in the amount of oil which is impregnated into different types of cables with immersion time in the oil.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is well known that when used as an electrical insulation, a polypropylene film has superior buckling strength, oil resistance, heat resistance, and electric breakdown strength as compared to a polyethylene film. We have made an extensive research and development work on the production of an insulating material by combining a polypropylene film with an electrically insulating paper, and found that a polypropylene laminate paper comprising an assembly of a biaxially oriented polypropylene film and an electrically insulating paper bonded to each other by a molten polyolefin proves excellent.

It has previously been attempted to use an insulating material produced by laminating polypropylene on an electrically insulating paper by the extrusion process. According to this process, the polypropylene used is an unoriented polypropylene which has inferior properties to biaxially oriented polypropylene.

This was experimentally confirmed as follows: Polypropylene was extruded in the molten state in a thickness of 100 μ on the extrusion process onto a 125μ *m* thick insulation paper for electric cables (to be abbreviated to OF 125 hereinafter). The resultant laminate paper was designated as (A). A 60μ *m* thick biaxially oriented polypropylene film was superposed on OF 125 while melt-extruding polypropylene in a thickness of 30μ *m* onto OF 125 by the extrusion process. The resulting laminate paper was designated as (B). The A.C. breakdown strength, oil resistance and oil flow resistance of these samples (A) and (B) were measured. The results are given in Table 1.

TABLE 1

Samples	AC Breakdown Strength (KV/mm)	Oil Resistance (Swelling Ratio %)	Coefficient of Inherent Oil Flow Resistance (cm^{-2})
(a) OF 125/unoriented polypropylene 100 μm	108.7	11	1.8×10^{13}
(b) OF 125/unoriented polypropylene 30 μm/biaxially stretched polypropylene 60 μm	121.6	3	3.0×10^{12}

In Table 1, the AC breakdown strength is a value measured at 60 Hz with reference to OF oil-impregnated flat plate sample. The oil resistance is a ratio (swelling ratio) of the thickness of the sample before impregnation of OF oil to that of the sample which has been immersed for 30 days at 80° C in OF oil and completely swollen with OF oil. FIG. **5** shows that the quantity of oil exhausted from cable model for 30 minutes under constant pressure difference is plotted against immersed period at elevated temperature. The coefficient of inherent oil flow resistance in Table **1** means the value calculated from the value at the staurated point in FIG. **5**. The coefficient of inherent oil flow resistance is the oil resistance value at complete equilibrium of a model cable produced by using sample (A) or (B), which value has been corrected with reference to the oil pressure, measurement length, viscosity of OF oil, insulation thickness and conductor diameter. Larger values show that the inherent oil flow resistance of the material is large. It is seen from the results shown in Table 1 that the sample (B) consisting of the electrical insulation paper and the biaxially oriented polypropylene film is superior in AC breakdown strength and oil resistance. A greater difference is the oil flow resistance. Experience of the inventors of this invention indicates that if a cable has a coefficient of inherent oil flow resistance of about 6.2×10^{12} cm^{-2} or less, it can be used without any disadvantage against transient fluctuations in oil pressure which are inherent to cables. From this viewpoint, the sample (A) consisting of the insulating paper and the unoriented polypropylene poses a problem in practical use.

Biaxially oriented polypropylene films are relatively low in cost, and are superior to polyethylene films in heat resistance, oil resistance and electric breakdown strength. Therefore, they are preferred materials for laminate insulations based on an insulating paper. The inventors of the present invention studied an insulation material comprising an integrated assembly of an insulating paper and a biaxially oriented polypropylene film on the basis of the overall consideration of the above-mentioned results.

We then studied a method of incorporating an electrical insulating paper with a biaxially oriented polypropylene film. As a result, we have experimentally found that an insulation material consisting of an electrically insulating paper/an unoriented polyolefin/a biaxially oriented polypropylene film which was obtained by bonding the first and third components with the second component in the molten state by the extrusion process is by far superior. Examples of the polyolefin as an adhesive are polypropylene and an ethylene/propylene copolymer. The experimental results will be described below.

It is known that a biaxially oriented polypropylene film has poor adhesiveness. On the other hand, it is necessary to use an adhesive which does not adversely affect the dielectric characteristics of the insulation. In the experiments, laminate papers prepared by various known methods, and integrated assemblies of an electrically insulating paper and a biaxially oriented polypropylene film bonded to each other by an extrusion-molded molten polypropylene or ethylene/propylene copolymer adhesive were compared with each other in respect of bond strength, oil resistance, tan δ and impulse strength. The results are shown in Table 2. As samples, a 60 mμ thick biaxially stretched polypropylene film and a 35 μm thick insulating paper for electric cables were used.

TABLE 2

Samples	Peeling strength (g./15 mm.)	Oil resistance	Tan, percent	Impulse strength (KV./mm.)
(A) Integrated using molten polypropylene as an adhesive by the extrusion process.	50	No part peeled off	0.030	327
(B) Integrated using chlorinated polypropylene as an adhesive	0.5	Completely separated into the biaxially stretched polypropylene film and the insulation paper.	0.775	325
(C) Integrated using chlorinated rubber	8	do	1.013	302
(D) Integrated using polyurethane as an adhesive	4	do	0.142	310
(E) The biaxially oriented polypropylene was heatbonded to the insulating paper.	45	No part peeled off; but the surface became roughened.	0.035	280
(F) Integrated using a molten ethylene/propylene copolymer as an adhesive by the extrusion process.	138	No part peeled off	0.031	318

The peel strength is a value of the strength of a 15 mm wide sample measured by a tensile tester. The oil resistance is evaluated by observing the shape of the sample after it has been immersed for 5 days at 80° C in an alkylbenzene. The tan δ is a value measured at 60 Hz at 80° C while the sample contains the alkylbenzene impregnated therein. The impulse strength is a value measured with respect to a flat plate sample impregnated with the alkylbenzene same as in the case of the impulse strength, with the insulating paper being directed to the side of the positive pole.

As shown in Table 2, samples (A) and (F), which were produced by melting polypropylene or an ethylene/propylene copolymer by the extrusion process to make them filmy, and bonding a biaxially oriented film of polypropylene to an electrical insulating paper using said molten polypropylene or ethylene/propylene copolymer as an adhesive, were best balanced in respect of bond strength, oil resistance, tan and impulse strength. The biaxially oriented polypropylene film had been stretched to 48X (longitudinal stretch *x* transverse stretch).

In a laminate insulating paper obtained by bonding a biaxially oriented polypropylene to an electrically insulating paper by a molten polyolefin in the above-mentioned manner, the low rigidity of the biaxially oriented polypropylene film is compensated for by the electrically insulating paper. Furthermore, as stated already, such defects as the reduction in working efficiency or operability, which are seen in a plastic film insulation or an insulation made by alternately winding a plastic film and an electrically insulating paper, can be eliminated.

When such a laminate paper is used for electric cables, and wound on a conductor so that the electrically insulating paper faces the conductor, the polypropylene film surface does not face the conductor in an oil layer. Therefore, such an insulated cable does not produce a polar effect which is seen in the conventional plastic tape-wound cable which has weak resistance to positively polar impulses, and moreover proves far superior to oil-impregnated paper in respect of electric breakdown strength and dielectric loss.

Changes in electrical and physical characteristics according to the thickness of the polyolefin as an adhesive were examined with respect to polypropylene (unoriented polypropylene). Generally, an unoriented polypropylene film has inferior electric characteristics and oil resistance as compared to a biaxially oriented polypropylene film, and therefore, it is expected that the molten polypropylene should better be made into a film which is as thin as can retain the bond strength of the molten polypropylene. The inventors of the present invention confirmed this by basic experiments. Table 3 shows how the impulse strength and oil resistance (swelling property) of a laminate paper obtained by bonding a 40 μm thick biaxially oriented polypropylene film to a 70 μm thick insulating paper for electric cables using molten polypropylene adhesive in accordance with the extrusion process change with the thickness of the polypropylene film adhesive. The test was conducted by immersing the sample in an alkylbenzene and heating it at 80° C for 20 days.

TABLE 3

Thickness of molten polypropylene (μm)	Impulse Strength (KV/mm)	Swelling Ratio *
10	270	5.0
20	250	6.2
30	233	7.2
50	201	8.8
70	177	10.0

* The ratio of the thickness of the sample before kmpregnation to that of the sample which was heated at 80° C for 20 days in the alkylbenzene.

It is seen therefore that with increasing thickness of the polypropylene film adhesive, the impulse strength decreases, and the swelling of the sample by oil becomes greater. Hence, the thickness of the polypropylene film adhesive should preferably be as thin as possible. This swelling can be reduced by the compression characteristics of the biaxially oriented polypropylene film and electrically insulating paper. However, if a thin electrically insulating paper having low strength is used, it may possibly be cut by the swelling force of the polypropylene in the thickness direction. In view of this also, it is preferred that the thickness of the polypropylene film adhesive should be as thin as possible. To confirm this, we have conducted the following experiment.

The samples shown in Table 3 were cut into tapes with a width of 10 mm, with the application of a tension of 1 Kg, each of the samples was wound on a glass tube having a diameter of 12.5 mm in a thickness of about 5 mm, followed by immersion in an alkylbenzene. The sample was then heated at 80° C, and then taken out after a lapse of 30 days. The sample was unwound and it was found that the sample in which the thickness of the polypropylene film adhesive was 70 μ *m* torn off partially at the part of the insulating paper. This shows that owing to the swelling of the polypropylene, the paper was cut. The results of this experiment showed that the thickness of the polypropylene film adhesive should be about three-fourths or less of the thickness of the insulating paper to be used. In order to prevent the tear of the paper by the swelling of polypropylene, thick paper of high strength may be used. But if the proportion of the insulating paper in an assembly of the insulating paper, molten polypropylene and a bi-axially oriented polypropylene film becomes large, the advantage of using the biaxially oriented polypropylene film having excellent electrical properties is reduced. Accordingly, the insulating paper to be used should also be as thin as possible.

The biaxially oriented polypropylene film is available in a wide variety of thicknesses. Those having large thickness (about 100 μ *m* or more) cause a reduction in electric breakdown strength, and therefore, in the laminated paper of this invention, the thickness of the biaxially oriented polypropylene film should preferably be not more than about 100 μ *m*.

Confirmatory experiments relating to the influences of the thickness of the insulation paper to impulse strength will be described below.

Samples were prepared by bonding a 60 μ *m* biaxially oriented polypropylene film to an insulating paper of various thicknesses using 15 μ *m* thick polypropylene as adhesive in accordance with the extrusion process. Each of these samples was immersed in a cable oil, and changes of the impulse strength of the sample according to the thickness of the insulating paper were examined. The results are given in Table 4.

TABLE 4

Thickness of the insulating paper (μm)	Impulse Strength (KV/mm)
40	330
70	266
125	222
150	184
200	140

It is seen from the results shown in Table 4 that the electric breakdown strength becomes larger with decreasing thickness of the insulating paper.

Now, a 60 μ *m* thick biaxially oriented polypropylene film was bonded to a 125 μ *m* thick electrically insulating paper based on polypropylene fibers by means of polypropylene in accordance with the extrusion process. The resultant sample was immersed in an alkylbenzene, and the dielectric properties and the impulse strength of this sample were measured. The results are shown in Table 5.

TABLE 5

		Polypropylene Fiber-Based Insulating Paper (125 μm)	Polypropylene Laminate Paper of this Invention
tan δ (10 KV/mm)	50°C	0.017%	0.008%
	80°C	0.014%	0.008%
	100°C	0.015%	0.010%
Dielectric Constant (ε)		2.21	2.21
Impulse Strength (KV/mm)		128	208

It is seen from the results shown in Table 5 that the defect of low impulse strength possessed by a polypropylene fiber-based electrically insulating paper can be eliminated drastically by incorporating it with the biaxially oriented polypropylene film described above. Furthermore, by using an alkylbenzene which has low dielectric constant (ε), the dielectric constant (ε) of the entire composite can be further reduced, and the tan δ also decreases.

In the following, oil-impregnated electric power cables using the polypropylene laminate paper of this invention will be described.

FIG. **1** shows a sectional view of a single-core OF cable in accordance with this invention. The reference numeral **1** represents a copper or aluminum conductor; **2**, an internal semi-conductor layer; **21**, an external semi-conductor layer; **3**, an insulation layer composed of a tape of a polypropylene laminate paper of this invention consisting of a biaxially oriented polypropylene film and an electrically insulating paper and being impregnated with an insulating oil, for example OF-oil, dedecylbenzene tridecylbenzene mono-dialkylated naphthalene; **4**, a metal sheath; and **5**, an anti-corrosive layer.

Of late, superhigh voltage cables have been developed. In order to provide at low cost an extra-high voltage cable having a thin insulation layer and a decreased outer diameter which can be wound on a small-sized drum, the alternate current working stress should be increased to as high as 20 to 30 KV/mm from 7 to 15 KV/mm which is in current use. Therefore, the impulse, AC strength and tan δ (dielectric loss tangent), which pose a problem in setting the working stress, should have excellent stability over prolonged periods of time. A number of attempts have previously been made to employ plastic films, such as polyethylene or polycarbonate films, having low dielectric constant (ε) and low tan δ in extra-high voltage cables, as already mentioned above. These plastic films have good initial voltage resistance characteristics but have the defect of being considerably deteriorated in breakdown characteristics against repeated application of impulse or AC voltage for prolonged periods of time, and also have the disadvantage that they have temperature dependent characteristics, a property inherent in plastics and exert a large polar effect. Furthermore, creases may occur at the time of manufacture of the cables or building a transmission system using the cables, or because of packing action between the plastic films, there are problems of poor vacuum formation, poor impregnation of oil, and bad oil resistance. These difficulties set limitations on the practical use of the plastic films for cable insulation. On the other hand, oil-impregnated paper has been in wide use as an insulation layer of self-contained or type-filled oil-incorporated electric cables, of cables of 60 KV to 500 KV because of its superiority in various properties other than dielectric constant and dielectric loss tangent. However, the dielectric constant of such oil-impregnated paper is limited to 3.4–3.7, and its dielectric loss tangent is 0.1 percent at the lowest. Therefore, limitations are imposed by temperature increases owing to tan δ loss, and it has been considered difficult to build cables of the order of 1,000 KV even if forced cooling is applied.

In view of the above, the cable of this invention is so designed that the ratio of ε of an oil-impregnated tape layer to that of an insulation oil (ϵ_s/ϵ_e) is limited to 1-1.5, whereby stress on oil has been drastically reduced as compared with the conventional OF cables, and the voltage resistance of the entire cable has been improved.

FIGS. **2**-(*a*) and **2**-(*b*) show the results of an impulse breakdown test on a sheet impregnated with an alkylbenzene oil. FIG. **2**-(*a*) shows that when an electrically insulating paper having high air-impermeability is integrated with a biaxially oriented polypropylene film, an increase in voltage resistance can be obtained. With an air-impermeability of 200 Gurley seconds, the voltage strength is considerably decreased, and for practical purposes, this is a minimum allowable value. Paper having an air-impermeability lower than this value is unsuitable. FIG. **2**-(*b*) shows that when the insulating paper is provided on an oil layer surface facing the conductor, there is no polar effect of impulse strength, which is inherent in plastics. These facts indicate that the air-impermeability of the electrically insulating paper should be at least 200 Gurley seconds, and that the winding of the electrically insulating paper to face the conductor side is effective. Since paper with high air-impermeability is expected to have a great effect of trapping ions or electrons generated by a strong electric field, it is considered to contribute to an improvement in voltage strength. When in an OF cable utilizing a plastic film and an oil layer is provided on the side of a conductor, and the plastic surface is in contact with the oil layer, application of impulse of positive polarity to the conductor side causes a decrease in the intensity of the impulse owing to the collision of positive ions, etc. In other instances (for example, when an impulse of negative polarity is applied, or a cushioning material such as an insulating paper is interposed between the oil layer and the plastic surface), a decrease in voltage strength does not occur even by application of impulses of positive polarity.

For practical purposes, the insulation layer of a cable may be built by alternately winding a biaxially oriented polypropylene film and an electrically insulating paper, but since the polypropylene surface more frequently faces the conductor side in the oil layer, the voltage strength decreases for the abovementioned reason and the polar effect of the impulse becomes greater. This method is therefore not so preferred.

FIG. **3**-(*a*) and **3**-(*b*) are enlarged sectional views of the insulating layer produced according to this invention. The reference numeral **1** represents a copper or aluminum conductor; **2**, an internal semi-conductor layer; **3**, an insulation layer of a polypropylene laminate paper according to this invention, F showing an electrically insulating paper, G showing a biaxially oriented polypropylene film, and O showing an insulation oil layer.

A tape-wound model cable containing an insulation layer composed of a OF paper with high air-impermeability (35 μ thick) and a 60 μ thick biaxially oriented polypropylene bonded to each other by CPP was immersed in an alkylbenzene oil, and pressed to conduct an impulse breakdown strength test. The results are shown in FIG. 4.

It is seen from this figure that the impulse strength of this cable improved about 50 percent, over the conventional OF model cable. It can be concluded from these results that the working stress near the conductor can be increased to 20 to 30 KV/mm, and there can be produced cables of the order of 1,000 KV having a drastically reduced insulation thickness and being capable of being wound up on a drum.

The electric cables in which the polypropylene laminate paper of this invention is wound possess the characteristics of both the plastic and insulating paper, and are free from creases which pose problems at the time of building a transmission system using the cables and have improved oil impregnating properties as well as improved electrical properties.

In other words, by suitably controlling the thickness of biaxially oriented polypropylene to be bonded to a fiber-based paper, dielectric constant (ϵ) can be easily controlled within 2.2–3.4, and the electric field can be relaxed by the difference in ϵ of the insulation layer.

Improvement in voltage strength can be achieved since the ratio of the dielectric constant between the insulation tape layer and the insulation oil (ϵ_s/ϵ_e) approaches 1 and the voltage can be borne by the polypropylene laminate paper having high voltage strength. Furthermore, the dielectric loss tangent of the cable can be maintained at 0.05 percent or less, which is considered to be difficult with an oil-impregnated paper, owing to the low tan δ characteristic of biaxially oriented polypropylene.

Furthermore, there can be produced electrically stable cables or reduced temperature effect or polar effect on impulse. Because of these advantages, the working stress increases, and the insulation thickness can be made smaller, which in turn leads to a drastic curtailment of cost for production of cables of the order of 60 to 500 KV. It is also possible to build cables of the order of 1,000 KV which can be wound on a drum unlike the conventional ones. From the process viewpoint, the drying step can be shortened because polypropylene is non-hygroscopic. The cables of this invention also have the advantage that they are free from crease formation caused by bending at the time of manufacture of the cables and building of a transmission system.

What is claimed is:

1. An electrically insulating polypropylene-paper laminate consisting of an integrated assembly of an electrically insulating paper and a biaxially oriented polypropylene film bonded to each other by an adhesive consisting of a melt-extruded polyolefin selected from the group consisting of polypropylene and a propylene copolymer containing a major proportion of propylene units, the thickness of said adhesive being less than the thickness of each of said paper and said film and being as small as possible without substantially sacrificing the bond strength exhibited between said electrically insulating paper and said polypropylene film.

2. The laminate of claim **1** wherein said polyolefin adhesive is an unoriented polyolefin.

3. The laminate of claim **2** wherein the air-impermeability of said electrically insulating paper is at least 200 Gurley seconds.

4. The laminate of claim **3** wherein the thickness of said biaxially oriented polypropylene film is not more than 100 μm.

5. The laminate of claim **3** wherein the thickness of said polyolefin adhesive is not more than 0.75 times the thickness of said electrically insulating paper.

6. An oil-impregnated electric power cable comprising an electrical conductor and insulation surrounding said conductor, at least a portion of said insulation comprising an electrically insulating polypropylene-paper laminate consisting of an integrated assembly selected from the group consisting of polypropylene and a propylene copolymer containing a major proportion of propylene units, the thickness of said adhesive being less than the thicknesses of each of said paper and said film and being as small as possible without substantially sacrificing the bond strength exhibited between said electrically insulating paper and said polypropylene film, said electrically insulating polypropylene-paper laminate having an electrically insulating oil impregnated therein.

7. The electric power cable of claim **14** wherein said electrically insulating polypropylene-paper laminate is wound around said conductor with the paper side of said laminate facing the conductor and wherein said electrically insulating paper has an air-impermeability of at least 200 Gurley seconds.

8. The electric power cable of claim **7** wherein the thickness of said biaxially oriented polypropylene film is not more than 100 μm and wherein the thickness of said polyolefin adhesive is not more than 0.75 times the thickness of said electrically insulating paper.

9. The electric power cable of claim **7** wherein said polyolefin adhesive comprises an unoriented polyolefin.

10. The electric power cable of claim **7** wherein the ratio of the dielectric constant (ϵ) of said electrically insulating polypropylene-paper laminate to the dielectric constant (ϵ) of said electrically insulating oil varies from 1 to 1.5.

11. The electric power cable of claim **7** wherein the dielectric loss tangent thereof is not more than 0.5 percent.

12. The process for producing the electric power cable of claim **15** comprising:

1. contacting said paper with water wherein said polypropylene-paper laminate absorbs moisture;
2. winding the moisture-containing polypropylene-paper laminate around said conductor while said laminate is wet;
3. drying to remove the moisture; and
4. impregnating said laminate with said oil.

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