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(54) **Electric power conductive cable**

(57) An electrical power cable comprising one or more conductors 1 provided with an insulating layer 3, a metal screen 5, a jacket 8 and between the metal screen 5 and the jacket 8 at least one separating layer 6 around the screen 5 and at

ERRATUM

SPECIFICATION NO 2032678

Page 6, line 12, *after* described. *start new paragraph insert* Amendments to claims filed on 9 February 1979
Amend claim 2:–

2. A power cable as claimed in claim 1, in which the humidity reducing material is selected from the group consisting of such water soluble salts, salts forming stable hydrates, acid and base anhydrides and materials capable of physical adsorption, which are capable of reducing the relative humidity of their surroundings to a value not exceeding 70%.

THE PATENT OFFICE
28 October 1981

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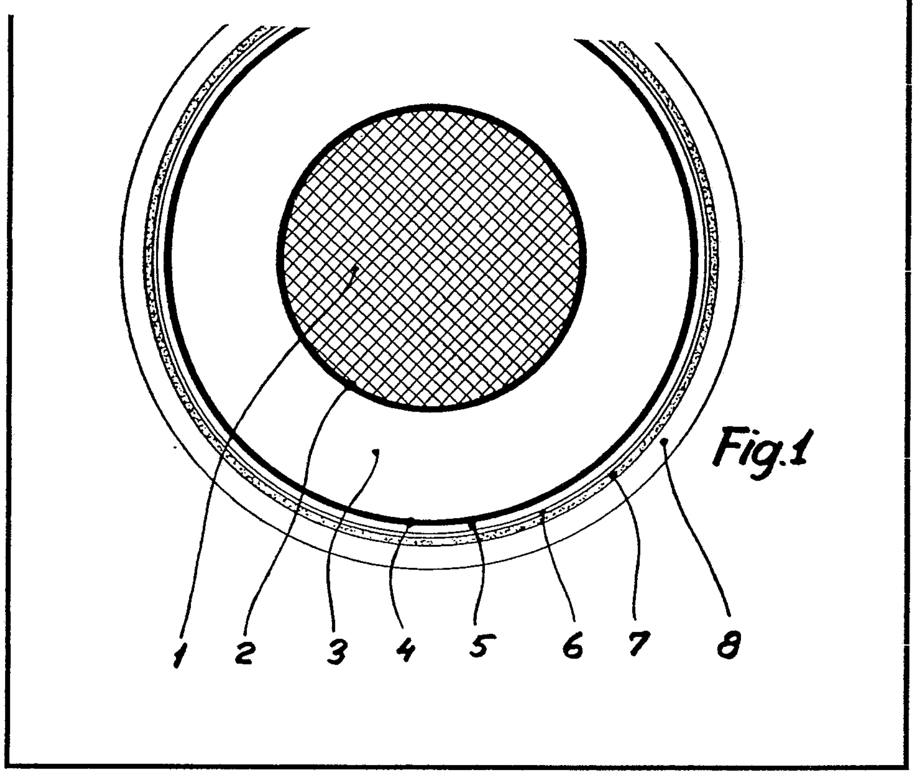

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(54) Electric power conductive cable

(57) An electrical power cable comprising one or more conductors 1 provided with an insulating layer 3, a metal screen 5, a jacket 8 and between the metal screen 5 and the jacket 8 at least one separating layer 6 around the screen 5 and at least one outer layer 7 of a paste material having a high degree of water resistance, compositions given, and in which one or more humidity reducing materials are incorporated. Semi-conductive layers 2 and 4 may be provided. Layer 6 may be self healing or seal under heat e.g. polyester/polyethylene laminate. Humidity reducing materials are e.g. Ca, Mg or Li chloride.

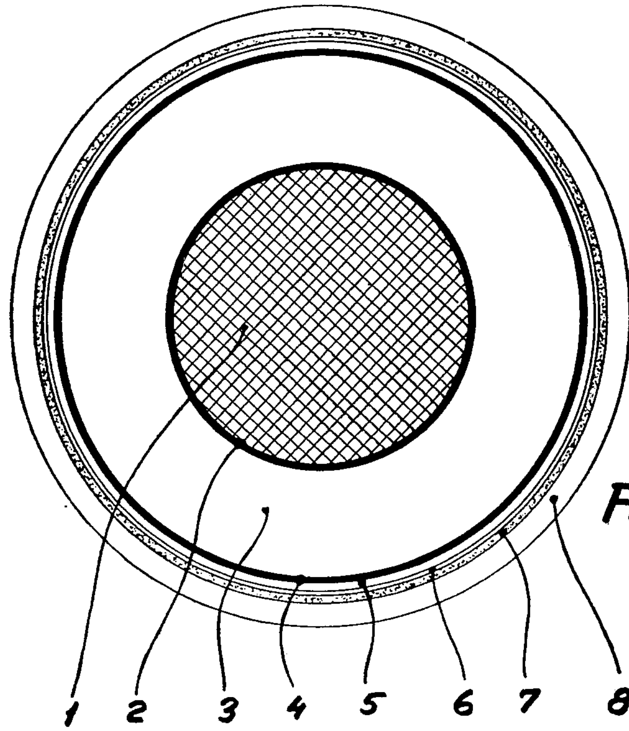

Fig.1

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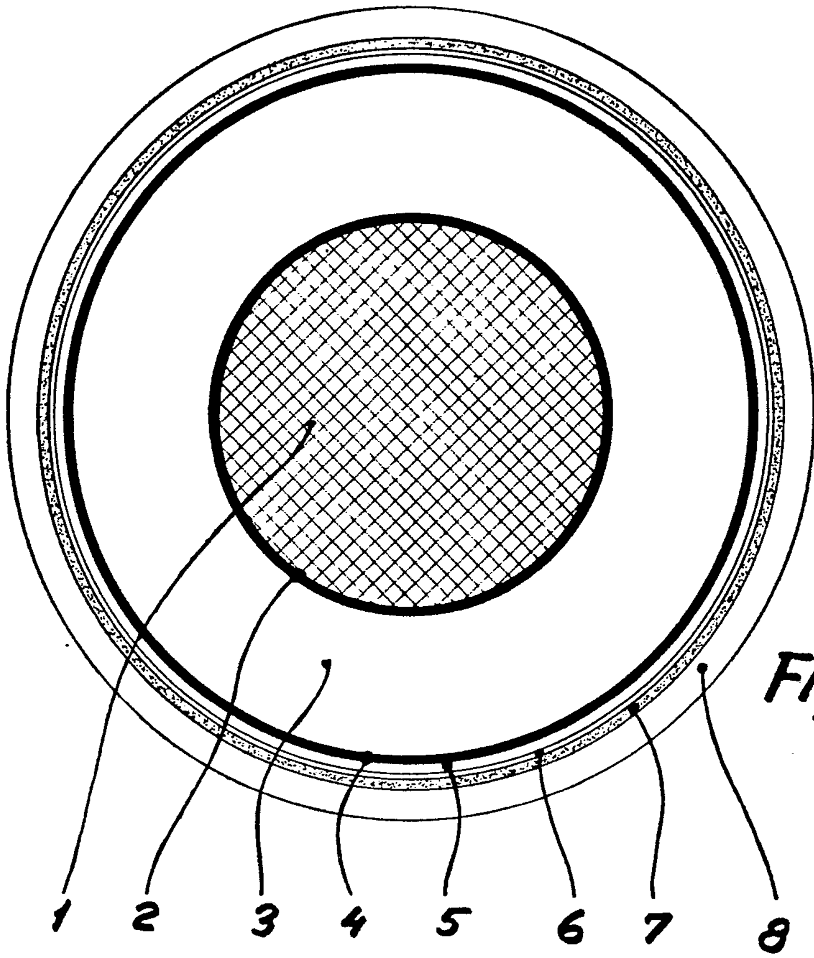

Fig.1

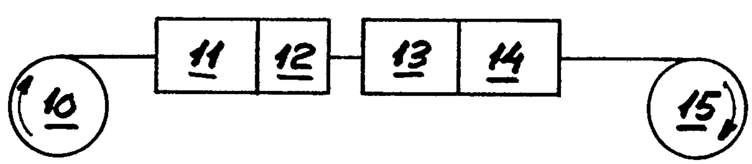

Fig.2

SPECIFICATION

Electric power conductive cable

This invention relates to electric power conductive cables with solid extruded insulation and more specifically to power cables having an improved resistance to corrosion *e.g.* due to mechanical damage of the outer jacket or sheath as well as an improved resistance to formation of the so-called ''water trees'' which will be discussed more fully below.

The invention further relates to a method for the manufacturing of such cables.

A typical electric power conductive cable which may be improved according to the invention comprises the following components:

(1) A conductor, made for example from Cu or Al,

(2) An inner semiconductive layer (the conductor screen) *e.g.* made from a cross-linked polyethylene copolymer containing semi-conductive particles *e.g.* carbon black,

(3) An insulating layer *e.g.* made from a polyethylene compound, a cross-linked polyethylene compound, an ethylene-propylene rubber compound or a butyl rubber compound,

(4) An outer extruded thermoplastic or cross-linked semi-conductive layer (the insulation screen) which may or may not be easily strippable from the insulating layer. Instead of extruding the layer, semi-conductive particles *e.g.* graphite may be applied by some sort of brushing or rubbing or may be applied in the form of a lacquer or paint layer containing a suitable binder,

(5) A metallic screen *e.g.* made from Cu or Al in the form of wires or tapes,

(6) An outer jacket or sheath *e.g.* made from PE or PVC.

Of course this general combination may be modified according to the intended use of the cable. One common embodiment is to include three conductors provided with layers (2)–(4) and a common metal screen or separate metal screens in a common jacket. Also semi-conductive layers (2) and (4) may be excluded, especially in low voltage cables.

Until now it has been a problem to provide such cables with a sufficent resistance to corrosion *e.g.* due to mechanical damage of the outer jacket or sheath together with a sufficient resistance to deterioration of the insulation caused by the well-known phenomen referred to as ''water treeing''or ''electrochemical treeing.

This phenomenon, which is not yet fully understood, occurs when exterior water migrates into certain areas of the insulation, where an electric field exists. minute voids filled with water and/or water-filled channels are formed which grow and unite in a shape resembling branches of a tree. A mechanism of such tree formation is described in detail in British Patent Specification No. 1477764, which also suggests certain remedies to this problem.

In British Patent No. 1477764 it is suggested to incorporate a water-solube electrolyte in part or in the whole of the insulation in an amount equal to 10^{-7}–10% by weight of the plastics insulation, which can be composed of *e.g.* polyethylene, cross-linked polyethylene, ethylene-propylene rubber or butyl rubber.

Preferably said electrolyte is a strong electrolyte, such as sodium chloride or sodium sulphate.

However, this solution is defective in certain respects since it is difficult to obtain a homogeneous distribution of the electrolyte even in the form of microparticles, and it is difficult if not impossible to avoid the positioning of some of the particles in or near the insulation surface where they may form sites for water trees even when they are dissolved and eventually leached out. If the particles are not homogeneously distributed so that aggregates are present or if the concentration in parts of the cable exceeds the upper limit of 1% by weight the insulation characteristics are adversely affected and/or infiltration of water due to osmotic pressure may arise.

As the presence of water and electrical field is essential for the initiation and growth of water treeing. One solution to the problem would be to provide the insulation layer with a water tight or impervious metal sheath, for example of extruded lead or aluminium or in the form of tapes which are folded and welded around the cable core.

However, such cables are expensive and difficult to handle especially in connecting work besides which there is a certain risk of mechanical damage resulting in penetration of water or moisture.

It has further been suggested in electric power cables comprising a conductor provided with one or more layers of extruded polymeric insulation as well as an inner and an outer semi-conductive layer, to arrange outside and separated from the outer surface of the conductor insulation a layer containing water soluble materials which in a manner known per se limit and stabilize the relative humidity of the surroundings,including the conductor insulation, to a value not exceeding 70%.

This suggestion is based on the experience that the origin of water trees is closely linked to voids or contaminations within the insulation and on the insulation surfaces, especially with contaminations in the form of or containing salts. However, experiments have shown that if the relative humidity in the insulation is lower than a certain limit, which seems to be about 70%, corresponding to the humidity in air above water which is saturated with NaCl, such water trees will not start growing even if there are contaminations in the insulation. These experiments are described in IEEE Trans. Electr. Insul. Vol EI–12 No. 6, December 1977.

Said materials capable of reducing the relative humidity can be chosen from among:

(a) Non-volatile materials which when dissolved in water reduce thr vapour preeure above the solution relatively to the vapour pressure of pure water at the same temperature. Suitable materials of this kind are water-soluble salts.

(b) Salts forming stable hydrates, such as $CaCl_2$, $MgCl_2$ and $Mg(ClO_4)_2$.

(c) Anhydrides of acids and bases, such as P_2O_5 or $H_2S_2O_7$.

(d) Materials capable of physical adsorption of water on the surface e.g. silica gel and molecular sieves.

Said humidity reducing materials placed in a layer outside and separated from the outer semi-conductive layer do not provide a water-tight barrier. The purpose of these materials is to reduce the relative humidity in the insulation to a predetermined percentage.

As stated above the active material must be placed somewhere between the insulation and the cable surroundings. More specifically, it has been suggested to mix the active material into a plastic material which is extruded on top of the already extruded insulation shield, or to sinter the material onto an insulation shield and apply a surrounding tape or jacket to prevent washing out of the material.

Still more specifically, the layer containing the active material may be extruded as a fourth preferably insulating layer on top of the common outer semi-conductive layer or the material may be incorporated in or adsorbed onto said layer.

Although these basic principles for preventing water-tree formation appear to be very advantageous a number of improvments in certain respects would seem advisable before such cables would lend themselves to safe long-term use.

First of all a great prejudice exists towards the use of salts corrosive per se in a cable comprising beyond the abovementioned polymer layers also a metal screen generally of Cu or Al on top of the outer semi-conductive layer. It must be expected that the more or less concentrated salt solutions eventually formed as moisture diffuses into the cable would give rise to a galvanic corrosion of the metal screen which might be even more detrimental to the cable than the water trees.

Furthermore, the presence of salt in a solid polymer material might result in a cracking of the polymer due to osmotic pressure, whereby water might have free access to the cable.

The above discussion has focussed on the problems linked to water tree formation, but another important and more general problem is to limit as far as possible the harmful effects from local mechanical damage of the cable, e.g. when a hole is knocked in the outermost protective layer, the cable jacket.

The danger of such local damage is especially that water penetrates into and flows in the longitudinal direction of the cable. This has of course many adverse consequences, for example that the outer semi-conductive layer, if it is of the easily strippable type, works loose from the insulation layer and that the metal screen and the carbon in the semi-conductive layer will act as a voltaic element in the presence of water leading to a severe corrosion of the screen.

In cables of the type proposed above where also salts are present the danger of corrosion of the metal screen is further increased.

It is known to counteract the consequences of such mechanical damage by providing the cable with a layer of a viscous paste capable of sealing small holes in the sheath. Such pastes contain, however, if they are to be suitably liquid, often constituents, such as oils which easily penetrate into the subjacent layers and make them swell. A consequence of such swelling is that the semi-conductive layer may become insulating, resulting in a deterioration of the cable properties.

It is further known to use annular, spaced blocking elements between the cable core and the jacket which block or impede the longitudinal penetration of the water. Other known remedies to prevent longitudinal water penetration is to fill the interstices in the cable with powders e.g. cellulose derivatives which in contact with water either swell or form a highly viscous phase and thus physically prevent the water penetration.

Though several solutions have thus been suggested to the problems of infiltration of water or moisture into electric cables, none of these solutions have definitively solved the problem, as they have either been focussed one-sidedly on the mechanical damage or on the formation of water trees and generally they bring about new drawbacks in replacement of the remedied ones. Thus, there is still no solution which to a great extent can prevent in a technically and financially acceptable manner both aspects of the infiltration of water without creating new adverse effects.

The object of the invention is to provide such a solution.

More specifically it is an object of the invention to provide electric cables which:

(1) effectively counteract the occurrence of water trees for long periods,

(2) have no inherent danger of corrosion,

(3) effectively counteract or at least limit the water ingress as well as the longitudinal spreading of the water when the cable is mechanically damaged,

(4) entail no risk of swelling of semi-conductive and insulation layers,

(5) leave the electrical characteristics of

the cable unaffected, and

(6) allow conventional connection work.

This object is achieved by the cable according to the invention which may be of any of the general types referred to above thus comprising one or more, e.g. three, conductors provided with an insulating layer and optionally an inner and outer semi-conductive layer and a metal screen, and further comprising as the characteristic features at least one separating layer around the metal screen and at least one outer layer of a paste material having a high degree of water resistance and in which one or more humidity reducing materials are incorporated.

Preferably said humidity reducing materials are chosen from among the abovementioned water soluble salts or salts forming stable hydrates. The most preferred compounds are $CaCl_2$, $MgCl_2$ and LiCl.

The separating layer must have sufficient barrier properties to prevent ingress of water possibly containing dissolved salts and thus to prevent corrosion of the subjacent metal screen. Further, it must resist oily materials and additives which are present in the paste material to secure satisfactory flow properties, since their penetration would be detrimental to the subjacent semi-conductive and insulating layers.

A suitable material for this separating layer from a barrier point of view is a polyester material which can be formed to a film such as a polyethylene terephthalate.

To obtain maximum security it is preferred to use for the separating layer a material which besides having the necessary barrier properties also has self-sealing properties, or at least sealing properties under influence of heat. When such a layer is applied e.g. by folding or preferably winding the material in the form of a tape around the metal screen it may not be necessary to provide a separate sealing treatment since the heat from the later hot applied paste layer will promote the sealing of the overlappings of the folded layer or of the individual windings and further cause a contraction of the separating layer giving the necessary pressure during the sealing process for preventing distortion of the wires in the metal screen under processing and handling of the cable.

A particularly suitable material is a film of a polyester of the abovementioned type which is laminated on one or both sides with polyethylene.

Such a laminated film advantageously combines the good mechanical strength and excellent barrier properties of the polyester material especially towards organic solvents with the good sealing properties of the polyethylene and thus permits a free choice among a great number of paste materials and additives.

Suitable polyester films are marketed under the trade marks Hostaphan®, Mylar® and Melinex®.

Alternatively, a separating layer of an extrudable polymer material having the mentioned barrier properties may be extruded onto the metal screen thus giving the additional advantage of securing the underlying screen in place.

As for the paste material the critical criteria are the flow properties at the application temperature as well as the temperature of use, the water resistance and the ability to contain sufficient amounts of humidity reducing additives while retaining the flow properties as water is absorbed by the additives. Correspondingly, the additives should not adversely effect the flow properties of the paste material.

Further the paste must have such properties, and the additive must be incorporated in such a manner that it will not be easily washed out of the paste.

In this respect it may be advantageous to provide two paste layers of which only the inner layer contains humidity reducing additives.

Suitable materials for the paste are e.g.

(a) Mixtures of a low-molecular polymer material chosen from among polyisobutylene, atactic polypropylene, and atactic polybutene with a natural or synthetic wax having a melting point of about 50–250°C, preferably 100–175°C and a viscosity of about 10^3–10^5 cP at the application temperature.

(b) Mixtures containing about 5 to 70 parts by weight of polyisobutylene (viscosity 20,000–500,000 cP at 20°C), about 95 to 30 parts by weight of atactic polypropylene or atactic polybutene, and up to about 1 part by weight of an oxidation stabilizer (preferably a sterically hindered phenol).

(c) Mineral oil products on paraffinic or aromatic basis thickened with clay (e.g. in the form of bentonite) aluminium stearate borate, pyrogenic silica (as e.g. Aerosil), and/or with carbon black.

(d) Petolatum or petroleum jellies with melting points of about 50–60°C.

(e) Rubber-like copolymers of ethylene and aliphatic unsaturated esters e.g. vinylacetate, methyl acrylate, methyl methacrylate containing appr. 30% by weight of the ester monomer.

(f) Mixtures of butyl-rubber, polyisobutylene, thickening agent, rosin, and softenere e.g.

50–100 parts by weight butyl rubber
50–100 parts by weight polyisobutylene
1– 15 parts by weight thickening agent
1– 20 parts by weight hydrogenated rosin
100–500 parts by weight softener

A suitable mixture is obtained with the following materials

100 parts by weight Esso butyl 065
100 parts by weight "Vistanex LM–MS"
5 parts by weight "Hi–Sil 233"

10 parts by weight "Staybelite ester"
350 parts by weight "diethylhexyl phthalate"

(g) Polyisobutlyene with a molecular weight of about 100,000 or mixtures of polyisobutylene and asphalt or bitumen.

(h) Products on asphalt or bitumen basis containing oily and or rubber materials to secure satisfactory flow properties and facilitate the application of the paste layer; a suitable recipe is e.g.:

90 parts by weight asphalt 85/40
8 parts by weight rape seed oil 50/50
2 parts by weight 60% rubber latex.

All the abovementioned materials and mixtures can be modified and/or made cheaper by addition of inert fillers e.g. calcium carbonate, calcium magnesium carbonate and clay in an amount of up to 300 parts by weight per 100 parts by weight of the materials and mixtures mentioned.

The humidity reducing material or materials are incorporated and homogenized in said filled or unfilled paste materials or mixtures so that the amount of active material per cm^2 surface of the finished cable is preferably not less than 0.01 g/cm^2 and preferably not more than 0.1 g/cm^2.

In a further embodiment the cable may be provided with two or more alternating separating layers and paste layers or with an inner semi-conductive paste layer without humidity reducing materials, a separating layer, and one or more outer paste layers.

In another embodiment a powder with swelling properties of the type mentioned above may be applied between the separating layer and the metal screen. This has the advantage that an embedding of the metal screen preventing a contact with the subjacent semi-conductive layer over a certain length, which might be feared if an inner paste material is used, will not take place. Thus no influence on the electrical properties is imparted to the cable and the powder is easy to apply without any dirtying problems.

All the above embodiments aim at providing the desired resistance according to the intended use and site of the finished cable.

It will be seen that the characteristic combination of a separating layer and a paste layer containing humidity reducing materials effectively fulfils the above objects (1)–(6).

Thus the occurrence of water trees is counteracted by the humidity reducing material in the paste layer.

No inherent danger of corrosion is present due to the separating layer which further prevents swelling of the subjacent layer and facilitates removal of the paste layer without dirtying the cable thus allowing an easy restoring of the paste layer in cable joints.

The water ingress and longitudinal spreading is effectively counteracted by the paste layer, being self-healing when machanical damage occurs.

All in all, the combination leave the electrical characteristics of the cable unaffected.

The invention further relates to a method of manufacturing cables of the types described, said method being characterized by the features defined in the characterizing clause of claim 12.

An embodiment of the invention will now be described, by way of an example, with reference to the accompanying drawing, in which:–

Figure 1 shows a cross-section of an embodiment of a power cable according to the invention, and

Figure 2 schematically illustrates the manufacture of a cable according to the invention.

Fig. 1 shows a cross-section through an embodiment of a cable according to the invention, where items 1 to 5 and 8 are traditional parts of a power cable. Thus the conductor 1 is surrounded by an inner semi-conductive layer 2, an insulation layer 3, an outer semi-conductive layer 4 and a metal screen 5, all being of any desired material and thickness.

The separating layer 6 may be a folded, wound or extruded layer as explaimed above and it is surrounded by the paste layer 7 which contains the humidity reducing material. 8 represents the outer jacket.

As stated above the paste layer 7 may consist of two layers of which only the inner layer contains humidity reducing material.

In an embodiment not shown a semi-conductive paste or a powder layer with swelling properties may further be provided between semi-conductive layer 4 and separating layer 6, and also humidity reducing paste layer 7 may be surrounded by a further separating layer and a further paste layer.

Fig. 2 schematically illustrates the manufacture of a cable according to the invention.

The conductor or conductors are provided with the layers 2–5 shown on Fig. 1 in any known manner and supplied from a reel 10. Optionally powder or semi-conductive paste is applied by means 11 whereafter a separating layer is applied by winding means 12 or by folding or extrusion means.

The cable is then passed through a box 13 where hot paste is applied, preferably in the form of stream flowing downward onto the cable and spreading over its periphery. At the outlet of the box the cable passes a stripper removing excessive paste and is directly introduced into the extruder 14 where the jacket is applied.

The finished cable is collected on a take off reel 15.

If desired one or more further paste boxes and/or winding means may be arranged between box 13 and extruder 14.

In another embodiment of the invention the cable delivered from the reel 10 may already be provided with the separating layer and optionally a subjacent layer of powder or semi-conductive paste.

The invention has been described above with particular relation to high-voltage power cables provided i.a. with semi-conductive layers. However, the invention is not limited to such cables but in its characteristic principles applies equally well to other types of electrical cables and wires where resistace to corrosion and water tree formation is of importance.

CLAIMS

1. An electrical power conductive cable comprising one or more conductors provided with an insulating layer, a metal screen, an outer jacket, and between the metal screen and outer jacket at least one separating layer around the metal screen and at least one outer layer of a paste material having a high degree of water resistance and in which one or more humidity reducing materials are incorporated.

2. A power cable as claimed in claim 1, in which the humidity reducing material is selected from the group consisting of such water soluble salts, salts forming stable hydrates, acid and base anhydrides and materials capable of physical adsorption, which are capable of reducing the relative humidity of their surroundings to a value not exceeding 10%.

3. A power cable as claimed in claim 1 or claim 2, in which the salt is $CaCl_2$, $MgCl_2$ or LiCl.

4. A power cable as claimed in any preceding claim, in which the separating layer consists of a polyester material with barrier properties towards water and oily materials.

5. A power cable as claimed in claim 4, in which the separating layer has self-sealing properties or sealing properties under influence of heat.

6. A power cable as claimed in claim 5, in which the separating layer consists of a polyester material laminated at least on one side with polyethylene.

7. A power cable as claimed in any preceding claim, in which the paste material is selected from the group consisting of

(a) Mixtures of a low-molecular polymer material chosen from amoung polyisobutylene, atactic polypropylene, and atactic polybutene with a natural or synthetic wax having a melting point of about 50–250°C, preferably 100–175°C and a viscosity of about 10^3–10^5 cP at the application temperature

(b) Mixtures containing about 5 to 70 parts by weight of polyisobutylene (viscosity 20,000–500,000 cP at 20°C), about 95 to 30 parts by weight of atactic polypropylene or atactic polybutene, and up to about 1 part by weight of an oxidation stabilizer (preferably a sterically hindered phenol)

(c) Mineral oil products on paraffinic or aromatic basis thickened with clay (*e.g.* in the form of bentonite), aluminium stearate borate, pyrogenic silica (as *e.g.* Aerosil), and/or with carbon black

(d) Petrolatum or petroleum jellies with melting points of about 50–60°C

(e) Rubber-like copolymers of ethylene and aliphatic unsaturated esters *e.g.* vinylacetate, methyl/acrylate, methyl/methacrylate containing appr. 30% by weight of the ester monomer

(f) Mixtures of butyl-rubber, polyisobutylene, thickening agent, rosin, and softeners *e.g.*

50–100 parts by weight butyl rubber
50–100 parts by weight polyisobutylene
1–15 parts by weight thickening agent
1–20 parts by weight hydrogenated rosin
100–500 parts by weight softener, *e.g.*
100 parts by weight Esso butyl 065
100 parts by weight "Vistanex LM-MS"
5 parts by weight "Hi-Sil 233"
10 parts by weight "Staybelite ester"
350 parts by weight "diethylhexyl phthalate"

(g) Polyisobutylene with a molecular weight of about 100,000 or mixtures of polyisobutylene and asphalt or bitumen

(h) Products on asphalt or bitumen basis containing oily and or rubber materials to secure satisfactory flow properties and facilitate the application of the paste layer, *e.g.*

90 parts by weight asphalt 85/40
8 parts by weight rape seed oil 50/50
2 parts by weight 60% rubber latex.

8. A power cable as claimed in any one of claims 1 to 7, having two paste layers of which only the inner layer contains humidity reducing materials.

9. A power cable as claimed in any of the preceding claims, having two or more alternating separating layers and paste layers.

10. A power cable as claimed in any of the preceding claims, having a semi-conductive paste layer without humidity reducing materials between the separating layer and the subjacent metal screen.

11. A power cable as claimed in any of claims 1 to 9, having a powder with swelling properties between the separating layer and the subjacent metal screen.

12. A power cable as claimed in any preceding claim, provided with an inner and an outer semi-conductive layer.

13. Method for the manufacturing of a power cable as claimed in claim 1, in which a cable core consisting of one or more conductors which in a known manner has been provided with an insulating layer and optionally an inner and outer semi-conductive layer and a metal screen is provided with a separating layer around the metal screen and at least one layer of a paste material having a high degree of water resistance and having incorporated one or more humidity reducing materials around said separating layer whereupon

an outer jacket is applied by extrusion in a known manner.

14. The method claimed in claim 13, in which the separating layer is applied by winding, folding or extrusion.

15. An electrical power conductive cable substantially as hereinbefore described with reference to and as illustrated in the accompanying drawing.

16. A method for the manufacture of an electrical power conductive cable substantially as hereinbefore described.

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