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(54) Title: ADHESION REDUCTION BETWEEN A METAL CONDUCTOR AND AN INSULATION SHEATH

(57) Abstract: The adhesive force between a metal conductor, e.g., tinned copper, and its insulation sheath, e.g., a crosslinked polyethylene, of a cable is reduced by applying an olefin oxide polymer, e.g., an ethylene oxide/butylene oxide copolymer or a butylene oxide/propylene oxide copolymer, to the metal conductor prior to forming the insulation sheath about the metal conductor.



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ADHESION REDUCTION BETWEEN A METAL CONDUCTOR AND AN INSULATION SHEATH

FIELD OF THE INVENTION

[0001] This invention relates to cables. In one aspect the invention relates to a method of reducing the adhesive force between a metal conductor and an insulation sheath while in another aspect, the invention relates to reducing the adhesive force by applying an olefin oxide polymer to the metal conductor prior to covering the conductor with the insulation sheath.

BACKGROUND OF THE INVENTION

[0002] One typical cable construction includes, among other things, a metal conductor surrounded by and in contact with an insulation sheath. The use of such cable often involves the need to strip the insulation sheath from the metal conductor to facilitate connecting the cable to an electrical device or another cable. The adhesive force, however, between the metal conductor, particularly a tin-coated (or "tinned") copper conductor, and a polymeric insulation sheath, particularly a crosslinked polymeric insulation sheath, can impede the stripping efficiency for such wire terminations. USP 4,427,469 provides a good description of such a cable, the problem of stripping the insulation sheath from the metal conductor, and one solution to this problem. However, the solution of the '469 patent requires, among other things, a special drawing apparatus for the shaping of the metal conductor.

SUMMARY OF THE INVENTION

[0003] In one embodiment the invention is a cable comprising (A) a metal conductor, e.g., a tinned copper conductor, (B) an olefin oxide polymer, e.g., an ethylene oxide/butylene oxide copolymer or a butylene oxide/propylene oxide copolymer, over and in contact with the metal conductor, and (C) a polymeric insulation sheath over and in contact with the olefin oxide polymer coating.

[0004] In one embodiment the invention is a method of reducing the adhesive force between a metal conductor and its insulation sheath in a cable, the method comprising applying an olefin oxide polymer to the metal conductor prior to forming the insulation sheath about the metal conductor.

[0005] The cable of this invention can exhibit a reduction in the adhesive force between the metal conductor and its insulation sheath of fifty percent (50%) or more as compared to a cable alike in all manners except without the olefin oxide polymer between the metal conductor and its insulation sheath.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Figure 1 is a schematic of an adhesive (or strip) force test apparatus.

[0007] Figure 2 is a bar graph reporting the strip force under various conditions on a solid tinned copper conductor.

[0008] Figure 3 is a bar graph reporting the strip force under various conditions on a stranded tinned copper conductor and at various time intervals.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0009] Unless stated to the contrary, implicit from the context, or customary in the art, all parts and percents are based on weight and all test methods are current as of the filing date of this disclosure. For purposes of United States patent practice, the contents of any referenced patent, patent application or publication are incorporated by reference in their entirety (or its equivalent US version is so incorporated by reference) especially with respect to the disclosure of synthetic techniques, product and processing designs, polymers, catalysts, definitions (to the extent not inconsistent with any definitions specifically provided in this disclosure), and general knowledge in the art.

[0010] The numbers and numerical ranges in this disclosure are approximate, and thus may include values outside of the range unless otherwise indicated. Numerical ranges include all values from and including the lower and the upper values, in increments of one unit, provided that there is a separation of at least two units between any lower value and any higher value. As an example, if a compositional, physical or other property, such as, for example, molecular weight, weight percentages, *etc.*, is from 100 to 1,000, then the intent is that all individual values, such as 100, 101, 102, *etc.*, and sub ranges, such as 100 to 144, 155 to 170, 197 to 200, *etc.*, are expressly enumerated. For ranges containing values which are less than one or containing fractional numbers greater than one (e.g., 0.01, 0.1, 1.1, *etc.*), one unit is considered to be 0.001, 0.01 or 0.1, as appropriate. For ranges containing single digit numbers less than ten (e.g., 1 to 5), one unit is typically considered to be 0.1. These are only examples of what is specifically intended, and all possible combinations of numerical values

between the lowest value and the highest value enumerated, are to be considered to be expressly stated in this disclosure. Numerical ranges and values are provided within this disclosure for, among other things, cable and cable component dimensions, temperature and the various characteristics and properties by which the components of this invention are defined.

[0011] “Comprising”, “including”, “having” and like terms are not intended to exclude the presence of any additional component, step or procedure, whether or not the same is specifically disclosed. In order to avoid any doubt, all compositions claimed through use of the term “comprising” may include one or more additional component substances, parts and/or materials unless stated to the contrary. In contrast, the term, “consisting essentially of” excludes from the scope of any succeeding recitation any other component, step or procedure, excepting those that are not essential to operability. The term “consisting of” excludes any component, step or procedure not specifically delineated or listed. The term “or”, unless stated otherwise, refers to the listed members individually as well as in any combination.

[0012] “Cable” and like terms mean at least one wire within a protective jacket or sheath. Often a cable is two or more wires bound together, typically in a common protective jacket or sheath. The cable can be designed for low, medium and high voltage applications. Typical cable designs are illustrated in USP 5,246,783, 6,496,629 and 6,714,707.

[0013] “Composition” and like terms mean a mixture or blend of two or more components.

[0014] “Polymer blend” and like terms mean a blend of two or more polymers. Such a blend may or may not be miscible. Such a blend may or may not be phase separated. Such a blend may or may not contain one or more domain configurations, as determined from transmission electron spectroscopy, light scattering, x-ray scattering, and any other method known in the art.

[0015] “Polymer” and like terms mean a macromolecular compound prepared by reacting (*i.e.*, polymerizing) monomers of the same or different type. “Polymer” includes homopolymers and interpolymers.

[0016] “Copolymer”, “interpolymer” and like terms mean a polymer prepared by the polymerization of at least two different monomers. These generic terms include classical

copolymers, i.e., polymers prepared from two different monomers, and polymers prepared from more than two different monomers, e.g., terpolymers, tetrapolymers, *etc.*

[0017] "Olefin oxide polymer" and like terms means a polymer containing a majority weight percent of units derived from one or more olefin oxide monomers, for example ethylene oxide or propylene oxide. Olefin oxide polymers include olefin oxide block copolymers. This term also includes blends of two or more olefin oxide polymers.

[0018] "Block" as used in the context of this invention means a polymeric segment of a copolymer which exhibits microphase separation from a structurally or compositionally different polymeric segment of the copolymer. Microphase separation occurs due to the incompatibility of the polymeric segments within the block copolymer. Microphase separation and block copolymers are discussed in "Block Copolymers-Designer Soft Materials", PHYSICS TODAY, February, 1999, pages 32-38.

Metal Conductor

[0019] The metal conductor of the cable of this invention can comprise any metal that will conduct an electrical current. These metals include copper and aluminum, either alone or in combination or alloyed with one or more other metals. Tinned copper, i.e., copper coated with tin, is a preferred metal conductor of this invention, and it is illustrated in USP 4,427,469. The conductor can be solid or stranded, i.e., individual wire strands twisted or otherwise bound or bundled together.

Olefin Oxide Polymer

[0020] The olefin oxide polymers used in the practice of this invention include diblock and triblock copolymers with block lengths of 1-10,000 olefin oxide units. In one embodiment the polymers typically contain at least 4 units derived from an olefin oxide. In one embodiment the total units in a block derived from one or more olefin oxides is typically between 4 and 300, more typically between 6 and 150 and even more typically between 8 and 50.

[0021] The olefin oxide polymer used in the practice of this invention is applied to the metal conductor prior to forming the insulation sheath over and about the conductor. The conductor is pretreated using one or more of any number of different techniques, e.g., dipping, spraying, *etc.*, so that most, i.e., greater than 50%, preferably all or near all, of the surface area of the conductor is coated or otherwise covered with the polymer. The amount of olefin oxide

polymer applied to the conductor, e.g., the thickness of the polymer layer over and in contact with the conductor, can vary widely and is typically a function of a number of variables including, but not limited to, the viscosity of the polymer and the application technique, parameters and equipment.

[0022] Olefin oxide polymers, also known as poly(alkylene) oxide polymers or polyether polymers, are products of the polymerization of one or more alkylene oxides, and they are generally water soluble. The olefin oxide polymers useful in the practice of this invention include, but are not limited to, one or more of olefin oxide homopolymer, olefin oxide random copolymer and olefin oxide block copolymer. The preferred olefin oxide polymers are polyethylene oxide, polypropylene oxide, polybutylene oxide and their copolymers, terpolymers, block copolymers and block terpolymers. The y may be alkoxy-terminated. Their molecular weight can vary widely so long as they are not so viscous as to be difficult to apply to the metal conductor. Polymers that are viscous at room temperature can be heated to reduce their viscosity so as to promote easy application to the conductor. The polyalkylene oxide polymers used in the practice of this invention may contain small amounts of additives such as antioxidants.

Insulation Sheath

[0023] The insulation sheaths of this invention comprise polyolefin, and these can be produced using conventional polyolefin polymerization technology, e.g., Ziegler-Natta, high-pressure, metallocene or constrained geometry catalysis. The polyolefins can be produced using a mono- or bis-cyclopentadienyl, indenyl, or fluorenyl transition metal (preferably Group 4) catalyst or constrained geometry catalysts (CGC) in combination with an activator, in a solution, slurry, or gas phase polymerization process. In one embodiment the polyolefin is ethylene ethylacrylate and/or ethylene vinyl acetate made under high pressure and free radical polymerization conditions. Polyolefins prepared with mono-cyclopentadienyl, mono-indenyl or mono-fluorenyl CGC can also be used in the practice of this invention. USP 5,064,802, WO93/19104 and WO95/00526 disclose constrained geometry metal complexes and methods for their preparation. Various substituted indenyl containing metal complexes are taught in WO95/14024 and WO98/49212. The form or shape of the polymer can vary to convenience, e.g., pellet, granule and powder.

[0024] In general, polymerization can be accomplished at conditions well known in the art for Ziegler-Natta or Kaminsky-Sinn type polymerization reactions, that is, at temperatures from 0-250°C, preferably 30-200°C, and pressures from atmospheric to 10,000 atmospheres (1013 megaPascal (MPa)). Suspension, solution, slurry, gas phase, solid state powder polymerization or other process conditions may be employed if desired. The catalyst can be supported or unsupported, and the composition of the support can vary widely. Silica, alumina or a polymer (especially poly(tetrafluoroethylene) or a polyolefin) are representative supports, and desirably a support is employed when the catalyst is used in a gas phase polymerization process. The support is preferably employed in an amount sufficient to provide a weight ratio of catalyst (based on metal) to support within a range of from 1:100,000 to 1:10, more preferably from 1:50,000 to 1:20, and most preferably from 1:10,000 to 1:30. In most polymerization reactions, the molar ratio of catalyst to polymerizable compounds employed is from 10^{-12} :1 to 10^{-1} :1, more preferably from 10^{-9} :1 to 10^{-5} :1.

[0025] Inert liquids serve as suitable solvents for polymerization. Examples include straight and branched-chain hydrocarbons such as isobutane, butane, pentane, hexane, heptane, octane, and mixtures thereof; cyclic and alicyclic hydrocarbons such as cyclohexane, cycloheptane, methylcyclohexane, methylcycloheptane, and mixtures thereof; perfluorinated hydrocarbons such as perfluorinated C₄₋₁₀ alkanes; and aromatic and alkyl-substituted aromatic compounds such as benzene, toluene, xylene, and ethylbenzene.

[0026] Polyolefins made under high pressure conditions are typically made in reactors that are often tubular or autoclave in physical design. The polyolefin polymer can comprise at least one resin or its blends having melt index (MI, I₂) from 0.1 to about 50 grams per 10 minutes (g/10min) and a density between 0.85 and 0.95 grams per cubic centimeter (g/cc). The preferred polyolefins are polyethylene with a MI of 1.0 to 5.0 g/10 min and a density of 0.918 to 0.928 g/cc. Typical polyolefins include high pressure low density polyethylene (HPLDPE), high density polyethylene (HDPE), linear low density polyethylene (LLDPE), metallocene linear low density polyethylene, and constrained geometry catalyst (CGC) ethylene polymers. Density is measured by the procedure of ASTM D-792 and melt index is measured by ASTM D-1238 (190C/2.16kg).

[0027] In another embodiment, the polyolefin polymer includes but is not limited to copolymers of ethylene and unsaturated esters with an ester content of at least about 5 wt%

based on the weight of the copolymer. The ester content is often as high as 80 wt%, and, at these levels, the primary monomer is the ester.

[0028] In still another embodiment, the range of ester content is 10 to about 40 wt%. The percent by weight is based on the total weight of the copolymer. Examples of the unsaturated esters are vinyl esters and acrylic and methacrylic acid esters. The ethylene/unsaturated ester copolymers usually are made by conventional high pressure processes. The copolymers can have a density in the range of about 0.900 to 0.990 g/cc. In yet another embodiment, the copolymers have a density in the range of 0.920 to 0.950 g/cc. The copolymers can also have a melt index in the range of about 1 to about 100 g/10 min. In still another embodiment, the copolymers can have a melt index in the range of about 5 to about 50 g/10 min.

[0029] The ester can have 4 to about 20 carbon atoms, preferably 4 to about 7 carbon atoms. Examples of vinyl esters are: vinyl acetate; vinyl butyrate; vinyl pivalate; vinyl neononanoate; vinyl neodecanoate; and vinyl 2-ethylhexanoate. Examples of acrylic and methacrylic acid esters are: methyl acrylate; ethyl acrylate; t-butyl acrylate; n-butyl acrylate; isopropyl acrylate; hexyl acrylate; decyl acrylate; lauryl acrylate; 2-ethylhexyl acrylate; lauryl methacrylate; myristyl methacrylate; palmityl methacrylate; stearyl methacrylate; 3-methacryloxy-propyltrimethoxysilane; 3-methacryloxypropyltriethoxysilane; cyclohexyl methacrylate; n-hexylmethacrylate; isodecyl methacrylate; 2-methoxyethyl methacrylate; tetrahydrofurfuryl methacrylate; octyl methacrylate; 2-phenoxyethyl methacrylate; isobornyl methacrylate; isooctylmethacrylate; isooctyl methacrylate; and oleyl methacrylate. Methyl acrylate, ethyl acrylate, and n- or t-butyl acrylate are preferred. In the case of alkyl acrylates and methacrylates, the alkyl group can have 1 to about 8 carbon atoms, and preferably has 1 to 4 carbon atoms. The alkyl group can be substituted with an oxyalkyltrialkoxysilane.

[0030] Other examples of polyolefin polymers are: polypropylene; polypropylene copolymers; polybutene; polybutene copolymers; highly short chain branched α -olefin copolymers with ethylene co-monomer less than about 50 mole percent but greater than 0 mole percent; polyisoprene; polybutadiene; EPR (ethylene copolymerized with propylene); EPDM (ethylene copolymerized with propylene and a diene such as hexadiene, dicyclopentadiene, or ethylidene norbornene); copolymers of ethylene and an α -olefin having 3 to 20 carbon atoms such as ethylene/octene copolymers; terpolymers of ethylene, α -olefin,

and a diene (preferably non-conjugated); terpolymers of ethylene, α -olefin, and an unsaturated ester; copolymers of ethylene and vinyl-tri-alkyloxy silane; terpolymers of ethylene, vinyl-tri-alkyloxy silane and an unsaturated ester; or copolymers of ethylene and one or more of acrylonitrile or maleic acid esters.

[0031] The polyolefin polymer of the present invention also includes ethylene ethyl acrylate, ethylene vinyl acetate, vinyl ether, ethylene vinyl ether, methyl vinyl ether, and silane interpolymers. One example of commercially available ethylene ethyl acrylate (EEA) is AMPLIFY from The Dow Chemical Company. One example of commercially available ethylene vinyl acetate (EVA) is DuPont™ ELVAX® EVA resins from E. I. du Pont de Nemours and Company.

[0032] The polyolefin polymer of the present invention includes but is not limited to a polypropylene copolymer comprising at least about 50 mole percent (mol%) units derived from propylene and the remainder from units from at least one α -olefin having up to about 20, preferably up to 12 and more preferably up to 8, carbon atoms, and a polyethylene copolymer comprising at least 50 mol% units derived from ethylene and the remainder from units derived from at least one α -olefin having up to about 20, preferably up to 12 and more preferably up to 8, carbon atoms.

[0033] The polyolefin copolymers useful in the practice of this invention include ethylene/ α -olefin interpolymers having a α -olefin content of between about 15, preferably at least about 20 and even more preferably at least about 25, wt% based on the weight of the interpolymer. These interpolymers typically have an α -olefin content of less than about 50, preferably less than about 45, more preferably less than about 40 and even more preferably less than about 35, wt% based on the weight of the interpolymer. The α -olefin content is measured by ^{13}C nuclear magnetic resonance (NMR) spectroscopy using the procedure described in Randall (*Rev. Macromol. Chem. Phys.*, C29 (2&3)). Generally, the greater the α -olefin content of the interpolymer, the lower the density and the more amorphous the interpolymer, and this translates into desirable physical and chemical properties for the protective insulation layer.

[0034] The α -olefin is preferably a C_{3-20} linear, branched or cyclic α -olefin. Examples of C_{3-20} α -olefins include propene, 1-butene, 4-methyl-1-pentene, 1-hexene, 1-octene, 1-decene, 1-dodecene, 1-tetradecene, 1-hexadecene, and 1-octadecene. The α -olefins also can contain a

cyclic structure such as cyclohexane or cyclopentane, resulting in an α -olefin such as 3-cyclohexyl-1-propene (allyl cyclohexane) and vinyl cyclohexane. Although not α -olefins in the classical sense of the term, for purposes of this invention certain cyclic olefins, such as norbornene and related olefins, particularly 5-ethylidene-2-norbornene, are α -olefins and can be used in place of some or all of the α -olefins described above. Similarly, styrene and its related olefins (for example, α -methylstyrene, etc.) are α -olefins for purposes of this invention. Illustrative polyolefin copolymers include ethylene/propylene, ethylene/butene, ethylene/1-hexene, ethylene/1-octene, ethylene/styrene, and the like. Illustrative terpolymers include ethylene/propylene/1-octene, ethylene/propylene/butene, ethylene/butene/1-octene, ethylene/propylene/diene monomer (EPDM) and ethylene/butene/styrene. The copolymers can be random or blocky.

[0035] The polyolefins used in the practice of this invention can be used alone or in combination with one or more other polyolefins, *e.g.*, a blend of two or more polyolefin polymers that differ from one another by monomer composition and content, catalytic method of preparation, *etc.* If the polyolefin is a blend of two or more polyolefins, then the polyolefin can be blended by any in-reactor or post-reactor process. The in-reactor blending processes are preferred to the post-reactor blending processes, and the processes using multiple reactors connected in series are the preferred in-reactor blending processes. These reactors can be charged with the same catalyst but operated at different conditions, *e.g.*, different reactant concentrations, temperatures, pressures, *etc.*, or operated at the same conditions but charged with different catalysts. The polymers and blends used in the practice of this invention typically have a density from 0.86 to 0.935 g/cc.

[0036] Examples of olefinic interpolymers useful in the practice of this invention include very low density polyethylene (VLDPE) (*e.g.*, FLEXOMER® ethylene/1-hexene polyethylene made by The Dow Chemical Company), homogeneously branched, linear ethylene/ α -olefin copolymers (*e.g.* TAFMER® by Mitsui Petrochemicals Company Limited and EXACT® by Exxon Chemical Company), and homogeneously branched, substantially linear ethylene/ α -olefin polymers (*e.g.*, AFFINITY® and ENGAGE® polyethylene available from The Dow Chemical Company). The substantially linear ethylene copolymers are more fully described in USP 5,272,236, 5,278,272 and 5,986,028. HPLDPE is a particularly preferred polyolefin for use in this invention.

[0037] Exemplary polypropylenes useful in the practice of this invention include the VERSIFY® polymers available from The Dow Chemical Company, and the VISTAMAXX® polymers available from ExxonMobil Chemical Company. A complete discussion of various polypropylene polymers is contained in *Modern Plastics Encyclopedia/89*, mid October 1988 Issue, Volume 65, Number 11, pp. 6-92.

[0038] The polymers utilized in the present may be crosslinked chemically or with radiation. Suitable crosslinking agents include free radical initiators, preferably organic peroxides, more preferably those with one hour half lives at temperatures greater than 120°C. Examples of useful organic peroxides include 1,1-di-t-butyl peroxy-3,3,5-trimethylcyclohexane, dicumyl peroxide, 2,5-dimethyl-2,5-di(t-butyl peroxy) hexane, t-butyl-cumyl peroxide, di-t-butyl peroxide, and 2,5-dimethyl-2,5-di-(t-butyl peroxy) hexyne. Dicumyl peroxide is the preferred crosslinking agent. Additional teachings regarding organic peroxide crosslinking agents are available in the Handbook of Polymer Foams and Technology, pp. 198-204, *supra*. The peroxide can be added to the polymer by any one of a number of different techniques including, but not limited to, addition of the peroxide directly to the extruder from which the polymer is ultimately extruded upon the cable, or absorbed into the solid polymer outside of the extruder either alone or in combination with one or more other additives, including the water-tree resistant agent.

[0039] Free radical crosslinking initiation via electron beam, or beta-ray, gamma-ray, x-ray or neutron rays may also be employed. Radiation is believed to affect crosslinking by generating polymer radicals, which may combine and crosslink. In the case of silane-containing polymers and copolymers, crosslinking can be carried out using moisture with a suitable catalyst. The Handbook of Polymer Foams and Technology, *supra*, at pp. 198-204, provides additional teachings.

[0040] The insulating compositions used in the practice of this invention may contain additional additives including but not limited to antioxidants, curing agents, cross linking co-agents, boosters and retardants, processing aids, coupling agents, ultraviolet absorbers or stabilizers, antistatic agents, nucleating agents, slip agents, plasticizers, lubricants, viscosity control agents, tackifiers, anti-blocking agents, surfactants, extender oils, acid scavengers, and metal deactivators. Additives can be used in amounts ranging from less than about 0.01 to more than about 10 wt% based on the weight of the composition.

[0041] The insulation sheath can also comprise one or more fillers and/or flame retardants. Examples of fillers and flame retardants include but are not limited to clays, precipitated silica and silicates, fumed silica calcium carbonate, ground minerals, aluminum trihydroxide, magnesium hydroxide and carbon blacks with arithmetic mean particle sizes larger than 15 nanometers. Fillers and flame retardants can be used in amounts ranging from minimally filled, e.g., 10, 5, 1, 0.1, 0.01 percent or even less, to highly filled, e.g., 40, 50, 60, 65 percent or even more, based on the weight of the composition.

[0042] Compounding of a cable insulation material can be effected by standard equipment known to those skilled in the art. Examples of compounding equipment are internal batch mixers, such as a Banbury™ or Bolling™ internal mixer. Alternatively, continuous single, or twin screw, mixers can be used, such as Farrel™ continuous mixer, a Werner and Pfleiderer™ twin screw mixer, or a Buss™ kneading continuous extruder. The type of mixer utilized, and the operating conditions of the mixer, will affect properties of a semiconducting material such as viscosity, volume resistivity, and extruded surface smoothness.

[0043] A cable containing a metal conductor and a polymeric insulation layer can be prepared with various types of extruders, e.g., single or twin screw types. A description of a conventional extruder can be found in USP 4,857,600. An example of co-extrusion and an extruder therefore can be found in USP 5,575,965. A typical extruder has a hopper at its upstream end and a die at its downstream end. The hopper feeds into a barrel, which contains a screw. At the downstream end, between the end of the screw and the die, there is a screen pack and a breaker plate. The screw portion of the extruder is considered to be divided up into three sections, the feed section, the compression section, and the metering section, and two zones, the back heat zone and the front heat zone, the sections and zones running from upstream to downstream. In the alternative, there can be multiple heating zones (more than two) along the axis running from upstream to downstream. If it has more than one barrel, the barrels are connected in series. The length to diameter ratio of each barrel is in the range of about 15:1 to about 30:1. In wire coating where the polymeric insulation is crosslinked after extrusion, the cable often passes immediately into a heated vulcanization zone downstream of the extrusion die. The heated cure zone can be maintained at a temperature in the range of about 150 to about 350°C, preferably in the range of about

170 to about 250°C. The heated zone can be heated by pressurized steam, or inductively heated pressurized nitrogen gas.

[0044] The invention is described more fully through the following examples. Unless otherwise noted, all parts and percentages are by weight.

SPECIFIC EMBODIMENT

Materials

[0045] Sample 1 is a control sample without any surface pretreatment.

[0046] Sample 2 is Solution (A) Satin FX coated. Satin FX is a block copolymer of ethylene and butylene oxide commercially available from The Dow Chemical Company (TDCC). The block length of ethylene oxide is 12 units and the block length of butylene oxide is 12 units.

[0047] Sample 3 is Solution (B1) UCON AP Low odor coated. UCON AP Low odor, a commercial TDCC product, is polypropylene oxide.

[0048] Sample 4 is Solution (B2) UCON 50-HB coated. UCON 50-HB, a TDCC product, is a block copolymer of propylene oxide and butylene oxide.

[0049] Sample 5 is MAC-743 coated. MAC-743 is commercially available from McGee Industries, and it is a specialty designed, high molecular weight polysiloxane polymer.

[0050] Sample 6 is Harrison Antistick coated. Harrison Antistick, commercially available from Harrison & Co., is an emulsion of 85% mineral oil, di-ethylene glycol, tall oil (liquid rosin), and caustic powder ash.

[0051] Sample 7 is MICHEM 66035 coated. MICHEM 66035, a Michelman Inc. product, is an emulsion of polyethylene wax in water.

[0052] Sample 8 is Super Lube coated. Super Lube, commercially available from Super Lube, is a suspension of polytetrafluoroethylene (PTFE) particles in synthetic oil.

[0053] Sample 9 is White Silicone Oil coated. White silicone oil, commercially available from Clearco, is an emulsion of silicone oil in water.

[0054] Sample 10 is Mc901 coated. Mc901, a commercial product from McGee Industries, is a dispersion of PTFE particles in water.

Sample Preparation

[0055] Cables are made by coating the halogen-free, flame retardant formulation described in the following table on tinned-copper conductors on a continuous vulcanization

(CV) line with a 2 1/2" extruder with length/diameter (L/D) = 24:1 screw under 45 feet per minute (fpm). The screw has a 3:1 compression ratio, with a metering depth of 0.090 inch. The extrusion temperature profile is 220F, 235F, 235F and 235F. Lubricants are loaded through a loading system. A stainless steel tube is attached to the crosshead on the continuous vulcanization line. This tube is aligned to the catenary angle of the CV line. A second stainless tube is vertically attached to the tube aligned with the line. Liquid lubricants are poured into the short vertical tube till the horizontal tube is filled. During wire extrusion lubricants are continuously added to the tube to maintain a flooding condition. The surfaces of the tinned copper conductors are pretreated with various fluids (sample 1 through sample 10) prior to coating of insulation onto the wire.

Halogen-Free, Flame Retardant Coating Composition

Component	Weight Percent
EEA-1	45.94
ATH	38
CaCO ₃	12
Silicone Oil	1
Silane	0.4
Peroxide	1.15
Antioxidants	1.51

EEA-1 is ethylene ethylacrylate from The Dow Chemical Company with a melt index of 1.3 at 190°C/2.16 kg and 15% ethyl acrylate.

ATH is aluminum trihydroxide with an average particle size of 1 micron and without a surface coating.

CaCO₃ is calcium carbonate with an average particle size of 1 micron and coated with stearic acid.

Silicone oil is DC 200 fluid.

Silane is vinyl triethoxysilane.

Peroxide is a,a'-bis(tert-butylperoxy)-di-isopropylbenzene.

The formulation was prepared in a batch mixer equipped with internal rotors and under ambient conditions.

Strip Force Measurement

[0056] One inch long wire specimens are prepared for the strip force test. One-half inch wire insulation on the 1" wire is carefully stripped off without disturbing the other 0.5" insulation for accurate measurement of strip force. Strip force (F) is tested on an Instron tensile testing instrument 10. Bare conductor end 11 of test specimen 12 was pulled in the direction of arrow 13 through plate 14 with hole 15 in the center (Figure 1). One clamp (not shown) of the Instron tester pulled the conductor end at 20"/min to remove insulation 16, and the other one clamp (not shown) gripped the insulation end. The maximum load is detected as the strip force F. For each sample, five specimens are tested to take the average strip force for comparison.

Results

[0057] Solution (A) is ethylene oxide and butylene oxide copolymer; Solution (B) is butylene oxide and propylene oxide copolymer. Solution (A) and Solution (B) effectively reduce the strip force between wire insulation and tinned copper conductors as shown in Figures 2 and 3. Samples 1 and 5-10 are comparative examples. Samples 2-4 are inventive examples. With the coatings of Solution A, B1 and B2, the strip force is significantly reduced compared to the control on both stranded and solid tinned conductors. The strip force is reduced to a minimal level by Solution B2. The Solution A, B1 or B2 are surprisingly found to be either more effective than or as effective as the commercially available lubricants in reducing the adhesion.

[0058] Although the invention has been described with certain detail through the preceding specific embodiments, this detail is for the primary purpose of illustration. Many variations and modifications can be made by one skilled in the art without departing from the spirit and scope of the invention as described in the following claims.

What is claimed is:

1. A cable comprising (A) a metal conductor, (B) an olefin oxide polymer over and in contact with the metal conductor, and (C) a polymeric insulation sheath over and in contact with the olefin oxide polymer coating.
2. The cable of Claim 1 in which the metal conductor is one of copper and aluminum.
3. The cable of Claim 2 in which the metal conductor is tinned copper.
4. The cable of Claim 3 in which the olefin oxide polymer coating is at least one of olefin oxide homopolymer, olefin oxide random copolymer and olefin oxide block copolymer.
5. The cable of Claim 4 in which the olefin oxide polymer is at least one of polyethylene oxide, polypropylene oxide, polybutylene oxide and their copolymers, terpolymers, block copolymers and block terpolymers.
6. The cable of Claim 5 in which the polymeric insulation sheath comprises a polyolefin polymer and contains at least one of a filler or flame retardant.
7. The cable of Claim 6 in which the polyolefin is at least one of polyethylene, polypropylene; polypropylene copolymers; polybutene; polybutene copolymers; highly short chain branched α -olefin copolymers with ethylene co-monomer less than about 50 mole percent but greater than 0 mole percent; polyisoprene; polybutadiene; ethylene copolymerized with propylene; ethylene copolymerized with propylene and a diene; copolymers of ethylene and an α -olefin having 3 to 20 carbon atoms; terpolymers of ethylene, α -olefin, and an unsaturated ester; copolymers of ethylene and vinyl-tri-alkyloxy silane; terpolymers of ethylene, vinyl-tri-alkyloxy silane and an unsaturated ester; copolymers of ethylene and one or more of acrylonitrile or maleic acid esters; ethylene ethyl acrylate, ethylene vinyl acetate, vinyl ether, ethylene vinyl ether, methyl vinyl ether, and silane interpolymers.
8. The cable of Claim 7 in which the polymeric insulation sheath is crosslinked.

9. A method of reducing adhesive force between a metal conductor and an insulation sheath in a cable, the method comprising applying an olefin oxide polymer to the metal conductor prior to forming the insulation sheath about the metal conductor.

10. The method of Claim 9 in which the olefin oxide polymer is applied to the metal conductor by dipping.

Figure 1

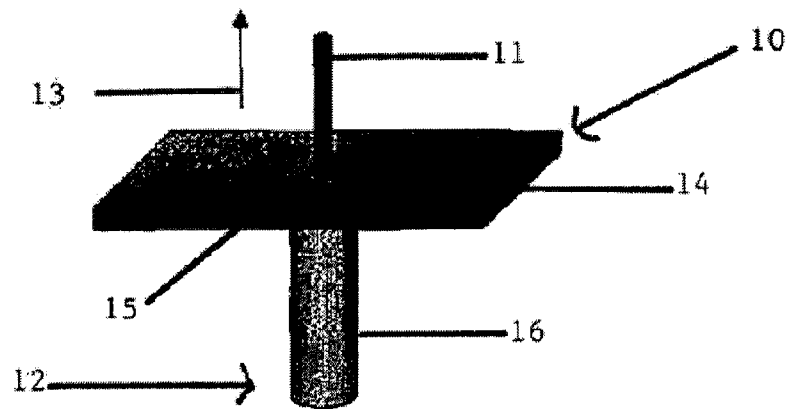


Figure 2

Strip Force under Various Coating Conditions on Solid Tinned Conductor

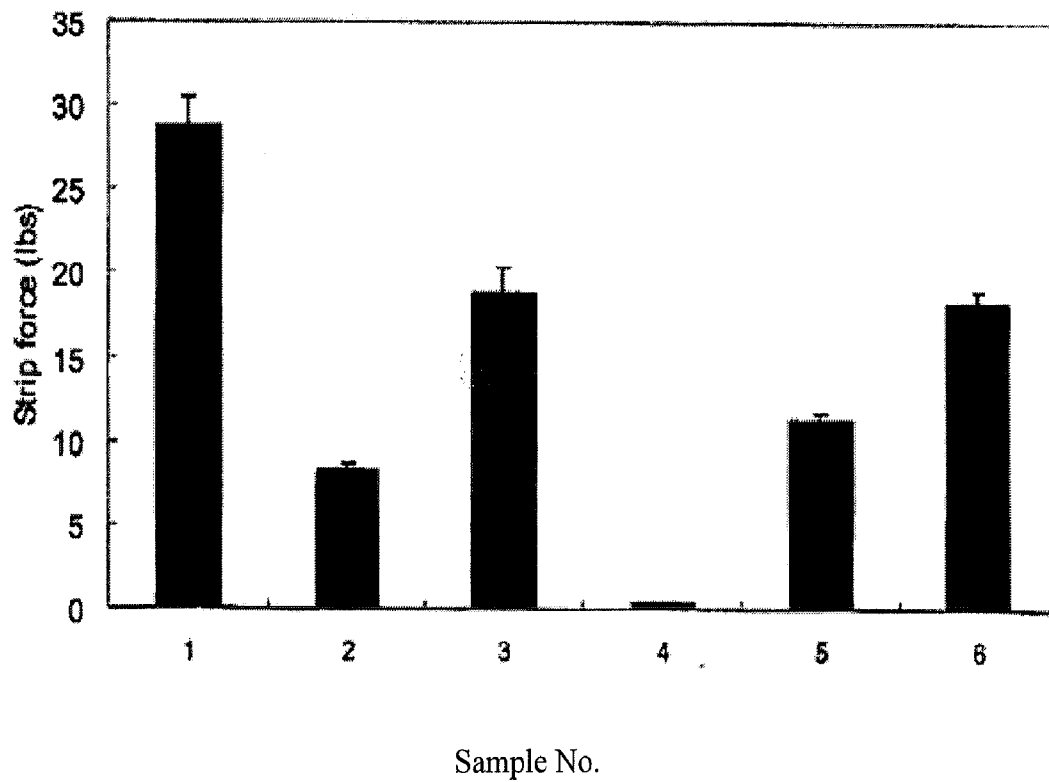
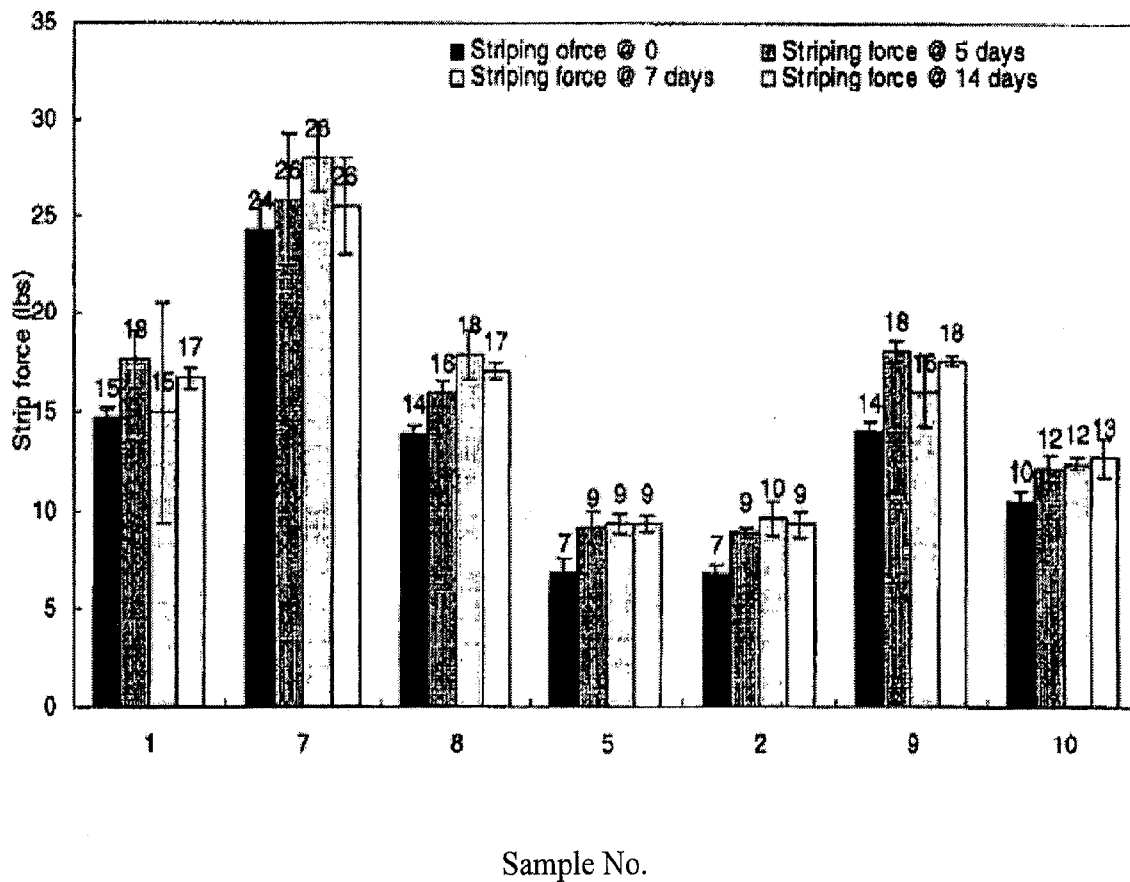


Figure 3

Strip Force under Various Coating Conditions on Stranded Tinned Conductor



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/023153

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01B3/18 H01B3/28 H01B3/30 H01B13/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 840 694 A (LUCZAK J) 8 October 1974 (1974-10-08) columns 2-4; claims 1-8; examples 1,2 -----	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
US 3840694	A	08-10-1974	CA 955810 A1	08-10-1974
