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HIGH VOLTAGE INSULATED ELECTRICAL CABLE WITH LAYER OF IRRADIATED SEMICONDUCTIVE ETHYLENE COPOLYMER

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Fig. 1.

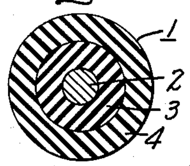


Fig. 2.

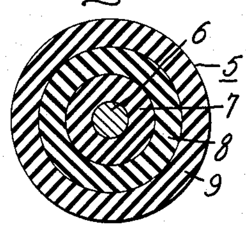
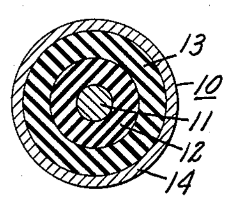


Fig. 3.



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HIGH VOLTAGE INSULATED ELECTRICAL CABLE WITH LAYER OF IRRADIATED SEMICONDUCTIVE ETHYLENE COPOLYMER

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This invention relates to electrical conductors and to insulation therefor. More particularly, it relates to such insulated conductors which are particularly useful for high voltage electrical applications.

Insulated conductors used for high voltage installations are particularly subject to corona discharge which occurs at the surfaces of insulation or when gas in voids or cavities within the insulation of such conductors is ionized. Such corona leads to deterioration of the insulation and its eventual failure.

Among the semiconductive grading insulating media previously used for such high voltage conductors were relatively thick elastomeric tapes wound about the conductor. While the electrically conductive grading material in such installations despite its bulk serves its purpose where the tape is actually in good contact with the conductor, the thickness of the tape, to fulfill strength requirements, inherently produces voids at points of overlapping, fostering the production of corona and defeating the purpose of the grading material. The same deficiency exists in such thick tapes also when the semiconductive tape is used over the main ground insulation or next to any outer shield or ground which may be present. Among the other types of tapes which have been used for such semiconducting purposes are the various fabric tapes which are impregnated with semiconductive materials such as graphite, carbon black, conductive resins and the like. As in the case of elastomeric tapes, the fabric tapes inherently produce voids when lapped over the conductor, or when applied as a sheet in the form of a tube. The fabric tapes in general do not have as good adhesion and hence as good contact with the insulation. The fabric based tapes are also deficient in that if the ground insulation overcoat is applied by extrusion, the heat and pressure of the extrusion often rupture the cloth or cause migration of the semiconductive particles within the cloth. The prior art semiconductive tapes and insulations are also subject to the defect that while they can be filled with carbon black or other conductive materials to a degree, the amount of such conductive filler which can be tolerated is generally limited so that the tailoring of resistivities to particular installations is often difficult if not impossible.

From the above, it will be quite apparent that there is a need for insulated electrical conductors which are capable of affording a wide range of resistivities, at the same time providing an insulation structure which is corona resistant, stable and unitary in character but which at the same time can be easily removed for splicing purposes.

A primary object, therefore, of the present invention is to provide cables having a composite insulation which is particularly resistant to corona formation and is possessed of the other above advantages.

Briefly, the invention relates to insulated electrical conductors or cables which are insulated with a first taped or sheet layer of semiconducting material comprising copolymers of polyethylene and mono-unsaturated materials as herein more specifically set forth along with a ground insulation of extruded polyethylene. In some applications, where indicated, the polyethylene ground insulation may be surrounded by a suitable second tape or sheet layer of semiconductive film and, where indicated, the polyethylene ground insulation may have thereover another layer of polyethylene copolymer material as described above which is electrically graded in desired manner and over which a metallic shield is wrapped or which is connected suitably to a ground. In some instances, the shield can be directly over the polyethylene ground insulation. Even when the copolymer outer layer has been finally heat shrunk in place, it can nevertheless still be unwound or stripped for easy splicing.

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Those features of the invention which are believed to be novel are set forth with particularity in the claims appended hereto. The invention will, however, be better understood and further advantages and objects thereof appreciated from a consideration of the following description and the drawing in which FIGS. 1 through 3 show various typical configurations, not to scale, of the present insulated cables.

The copolymers of polyethylene which are particularly useful in connection with the invention are those set forth in copending application S.N. 310,463, filed September 20, 1963. Among such materials are the copolymers of polyethylene with mono-unsaturated materials such as vinyl group-containing materials, including the vinyl esters such as vinyl acetate, the various acrylate materials such as the alkyl acrylates, including methyl, ethyl and hexyl acrylates, among others, and mono-unsaturated olefins such as propylene, butenes, pentenes, etc., which are used in such proportions with the ethylene as to produce partially crystalline thermoplastics as opposed to elastomers. It is necessary that these copolymerized materials be mono-unsaturated materials since any higher degree of unsaturation promotes undesirable cross-linking during preparation of the material which detracts from the flexibility and elasticity and other physical characteristics of the final product. The ethylene and mono-unsaturated material is copolymerized in manners well known to those skilled in the art and such products are commercially available as Union Carbide—DPDB–6169, DPDA–6168, DQDA–3270, DQDA–7268, DQDA–3269 and Du Pont ELVAX–150 and ELVAX–250, among others.

The above materials are particularly characterized by the fact that they can accept relatively large quantities of conductive fillers as well as non-conductive fillers. For example, it has been found that such irradiated copolymers as those described above will accept up to and over 100% or more by weight of filler having a particle size of from about 10 to 20 mμ based on the weight of the copolymer without undesirable loss of flexibility or other characteristics which are necessary for a suitable insulating tape. For fillers of larger particle size of from 500 to 700 mμ, up to about 400% by weight of filler can be accepted by the material without loss of flexibility. Mixtures of such grading materials can also be used. The filled copolymers which are used as the semiconducting or electrically grading layers are fully irradiated or irradiated to the point where they are form stable at temperatures of 200° C. and upward which are experienced when the polyethylene ground insulation is extruded over them. They can, of course, be fully oriented or stretched in which case the shrinkage of the tape when the overlayer is extruded on will cause shrinking of the inner layer and heat sealing which eliminates any potentially corona-forming voids. Alternatively, as above, the copolymer grading layer can be irradiated just to the point of form stability under extrusion temperature conditions and have added thereto a chemical cross-linking agent such as the various peroxides disclosed in British Patent 910,204 and U.S. Patent 2,916,481, among others, which will complete the cure of the material under the extrusion temperatures causing the inner layer to flow evenly and seal to the extruded ground insulation.

The ground insulation may consist of any of the usual polyolefins derived from monoolefins such as polyethylene, polybutylene, butyl rubber, ethylene-propylene rubber and blends and copolymers and terpolymers of such materials which are well known to those skilled in the art, and where polyethylene is mentioned herein it will be understood that any and all of such materials are included. Such polyethylene materials are sold under the name of Alathon by E. I. du Pont de Nemours & Company, Inc., by the Bakelite Company under the designations DE-2400, DYNH, etc., and by the Phillips Petroleum Company under the designations Marlex, 20, 50, etc. Butyl rubber is a copolymer of polyisobutylene and isoprene is sold by Enjay Chemical Company as is EPR ethylene-propylene copolymer. The polyolefin ground insulation may be used as such, or it may be cross-linked by irradiation or chemical curing agents which are activated by the heat of extrusion. Filled polyolefin materials can also be used, and among such fillers are the silica fillers of various sizes and types such as aerogels, fumed silica, metal silicate, titanium dioxide, zinc oxide carbonates such as carbamate, magnesium carbonate, carbon black and various carbides. Semiconducting fillers are here used in smaller amounts which will not impart conductivity to any extent.

The graded or semiconductive materials of the present invention are preferably provided in the form of tapes or sheets which are typically from about 2 mils to about 25 mils thick and which are filled with varying amounts of carbon black or other semiconducting or conductive material to provide resistivities for any particular application. A typical 10 mil thick material has a tensile strength of about 15 lbs. per inch of width, a yield point of 8 to 10 lbs. per inch of width and an ultimate elongation up to about 300%. Resistivities measured at room temperature may typically range from about 5 ohm-cm. to 500 ohm-cm. or more. For example, when a material, specifically Bakelite polyethylene-ethyl acrylate copolymer DPDB–6169, was filled with 25 parts of carbon black per 100 parts of copolymer, the resistivity was found to be 85 ohm-cm. When 40 parts of carbon black were used, the resistivity was lowered to 28 ohm-cm. At 60 parts of carbon black the resistivity was 4.5 ohm-cm. and at 75 parts the resistivity was 1.5 ohm-cm. These amounts of filler and even larger amounts up to four times the weight of the base material itself are accepted without embrittlement or prohibitive stiffening and are thus distinguished from the normal polyethylene polymers.

While the grading tape described above can be oriented or stretched and irradiated so that under the heat of extrusion of the ground insulation it will be shrunk about the conductor, it is sometimes preferred to cross-link such tapes by high energy electron irradiation to the point where they are thermoset or form stable and will not rupture under the conditions of heat and pressure experienced during extrusion but at the same time the irradiation dosage should be low enough so that sealing of the tape to itself and to the overlying polyethylene extruded material is not inhibited. Generally speaking, for the copolymers of the present invention radiation levels of 4 to 20 megaroentgens can be used with the preferable radiation level being between 6 and 10 megaroentgens at potentials of from 5×10^4 to 2×10^7 electron volts. It was found, for example, that when from 3.5 to 25 megaroentgens were used to irradiate a 5 mil thick tape of the above description, the tensile strength at 150° C. ranged from about 26 to 530 p.s.i. with heat sealing to itself and to overlying polyethylene occurring at a temperature of 150° C. and a pressure of 10 p.s.i.

Any of the usual well known methods of extrusion can be used. Typically, the temperatures of such extrusion range from about 180° C. to about 260° C. and the pressure from about 100 p.s.i. to 1000 p.s.i.

It will be apparent to those skilled in the art that one of the primary advantages of the present invention lies in the fact that the relatively thin taped layers which are used herein provide a definite size advantage over the much thicker extruded semiconductive layers of the prior art.

Referring to the drawing, there are shown several embodiments of the present invention, it being realized, of course, that others will occur to those skilled in the art. Shown in FIG. 1 is an insulated cable **1** having a central conductor **2** with a coating of the present semiconductive tape insulation **3** and ground insulation **4** of polyethylene type material. Shown in FIG. 2 is an insulated cable structure **5** with central conductor **6** with semiconductive insulation **7** thereover. A ground insulation **8** of polyethylene or polyolefin type material as described overlies semiconductive layer **7**. A further semiconductive layer **9** is placed about the extruded ground insulation layer **8**. A still further modification of the invention is shown in FIG. 3, wherein insulated cable structure **10** having a central conductor **11** has a taped layer of semiconductive material **12** and an overlying extruded layer of polyethylene ground insulation **13**. Grounding shield **14** is provided as an outer sheath.

The following examples will illustrate the invention, it being understood that they are not to be taken as limiting in any way.

EXAMPLE 1

A number 2–7 stranded conductor had extruded thereon a layer 220 mils thick of uncross-linked polyethylene with no semiconductive layer. The corona starting voltage of this cable varied from about 1,000 to 4,000 volts.

EXAMPLE 2

The cable of Example 1 was tubular wrapped with a layers 5 mils thick of copolymer DPDB–6169 which was filled with 67 parts of XC–72 Cabot carbon black having a particle size of from about 10 to 20 mμ, the carbon black being present in the amount of 67 parts by weight per 100 parts of copolymer. Overlying this semiconductive layer, there was extruded 220 mils of uncross-linked polyethylene. When tested as in Example 1, the corona starting voltage was found to be 35,000 volts.

EXAMPLE 3

A conductor similar to that of Example 1 was overlain with a carbon black filled fabric semiconductive wrap which was in turn overlain by 220 mils of cross-linked polyethylene. The corona starting voltage for this cable was found to be about 12,000 volts.

EXAMPLE 4

Example 1 was repeated except that cross-linked polyethylene was used as the insulation. The corona starting voltage was once again from 1,000 to 4,000 volts.

EXAMPLE 5

The conductor of Example 1 was tubular wrapped with a semiconductive layer as in Example 2 and overlain by extrusion with about 220 mils of cross-linked polyethylene which was in turn overlain with 5 mils of the present semiconductive tape of Example 2. The corona starting voltage of this cable was found to range from about 22,000 to 28,000 volts.

There are provided by the present invention insulated cable structures having composite insulation, the elements of which are characterized by similar coefficient of expansion and which are firmly bound one to the other, thus substantially increasing the corona starting voltage. The insulated cables are also characterized by compact size as compared to prior art wholly extruded composite insulations and the semiconductive elements can be loaded with large amounts of semiconductive materials to provide a wide range of insulated cables which are useful for varying installations. The tape materials of the present invention are also particularly useful in that they may be stripped or sealed to facilitate splicing where indicated.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A high voltage electrical cable having a conductor surrounded by a composite insulation comprising a first taped layer of irradiated semiconductive material comprising a copolymer of ethylene and a mono-unsaturated material selected from vinyl materials, acrylate materials and olefins and mixtures thereof filled with conductive material and a second extruded layer of ground insulation comprising a polyolefin.

2. A high voltage electrical cable as in claim **1** in which said copolymer is a colpolymer of ethylene and vinyl acetate.

3. A high voltage electrical cable as in claim **1** in which said copolymer is a copolymer of ethylene and alkyl acrylate.

4. A high voltage cable as in claim **1** in which said copolymer is a copolymer of ethylene and ethyl acrylate.

5. A high voltage electrical cable having a centrally located conductor and thereover a composite insulation comprising a first taped layer of irradiated semiconductive material comprising a copolymer of ethylene and a mono-unsaturated material selected from vinyl materials, acrylate materials and olefins and mixtures thereof, filled with semiconductive material, a ground innsulation of polyolefin extruded over said first taped layer, and overlying said ground insulation a second taped layer of similar semiconductive material.

6. A high voltage electrical cable as in claim **5** in which said copolymer is a copolymer of ethylene and vinyl acetate.

7. A high voltage electrical cable as in claim **5** in which said copolymer is a copolymer of ethylene and alkyl acrylate.

8. A high voltage electrical cable as in claim **5** in which said copolymer is a copolymer of ethylene and ethyl acrylate.

9. A high voltage electrical cable having a centrally located conductor with a composite insulation comprising a first taped layer of irradiated semiconductive material comprising a copolymer of ethylene and a mono-unsaturated material selected from vinyl materials, acrylate materials and olefins and mixtures thereof, filled with conductive material, and extruded over said taped layer a ground insulation of polyolefin which is in turn surrounded by a metallic shield.

10. A high voltage electrical cable as in claim **9** in which said copolymer is a copolymer of ethylene and vinyl acetate.

11. A high voltage electrical cable as in claim **9** in which said copolymer is a copolymer of ethylene and alkyl acrylate.

12. A high voltage electrical cable as in claim **9** in which said copolymer is a copolymer of ethylene and ethyl acrylate.

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