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[54] **ETHYLENE-PROPYLENE RUBBER INSULATED
 CABLE WITH CROSS-LINKED POLYETHYLENE
 STRAND SHIELDING**
 10 Claims, 3 Drawing Figs.

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 174/107, 174/110
 [51] Int. Cl..... H01b 11/06
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 174 (Shield); 156/51; 264/174

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ABSTRACT: A high-tension cable is made with a strand shield of cross-linked, conductive polyethylene compound and with insulation that is a proprietary compound of ethylene-propylene rubber. The insulation is approximately 48 percent ethylene-propylene amorphous copolymer; approximately 12 percent crystalline polyethylene homopolymer; and reinforcing fillers to provide adequate physical properties. The shield and insulation are extruded and cured simultaneously to obtain void-free bonding.

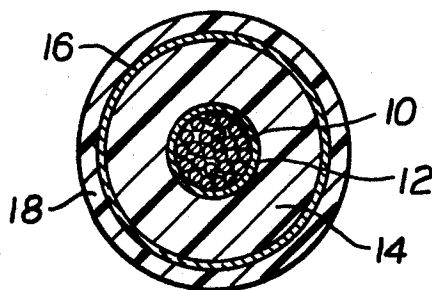


FIG. 1.

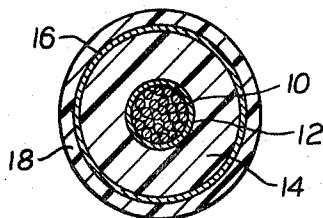


FIG. 2.

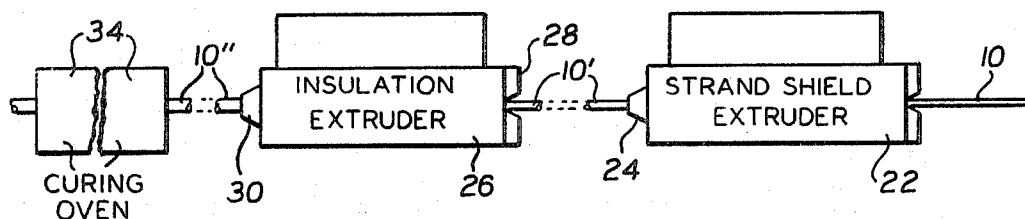
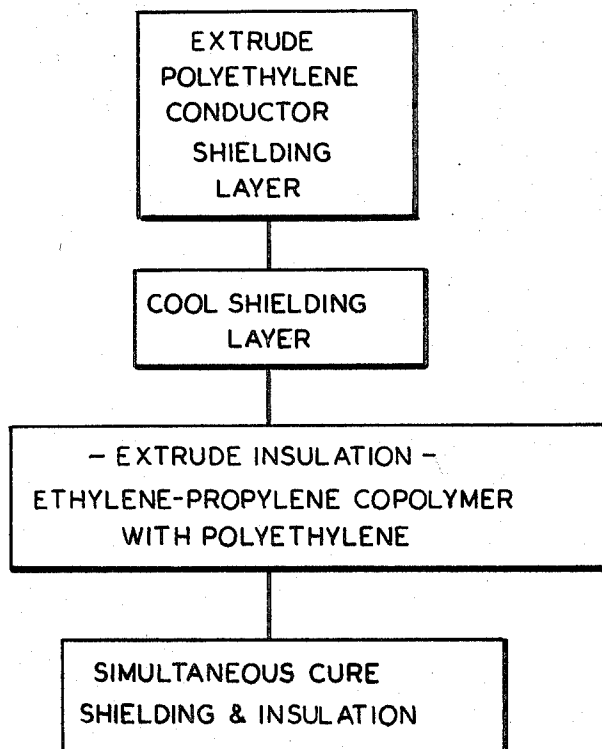


FIG. 3.



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ETHYLENE-PROPYLENE RUBBER INSULATED CABLE WITH CROSS-LINKED POLYETHYLENE STRAND SHIELDING

SUMMARY OF THE INVENTION

This invention provides an improved electrical cable for high-voltage power transmission. The cable has improved resistance to ozone and corona discharge; excellent insulating characteristics and aging properties, and greater flexibility that permits bending through shorter radii. The invention also provides a construction in which the conductor shielding is not forced into the interstices of a stranded conductor and this aids splicing and terminating operations by leaving a clean, free stripped conductor. The invention includes also a method of making the improved cable.

The two compounds are applied to a suitable conductor (i.e., copper stranded wire), preferably in a tandem extrusion operation, and are cured simultaneously. The strand shield of conductive chemically cross-linkable polyethylene is applied in the first stage of the tandem extrusion process, and provides a smooth outer surface upon which to apply the insulating compound. Being firm and of high green strength, and having a low coefficient of friction after a short period of air cooling following extrusion at elevated temperature, the strand shielding compound of conductive cross-linkable polyethylene may be passed through the guide tip of the second extruder, which applies the insulation compound, while still preserving the electrically desirable smooth outer surface of the strand shielding material. At this stage of the process, the lower processing temperature of the ethylene-propylene rubber compound, as opposed to the processing temperature of the cross-linked polyethylene shielding compound, plays an important part in maintaining the original smooth shape of the cross-linkable conductive polyethylene layer previously extruded.

Extruded strand shielding of chemically cross-linked polyethylene has numerous desirable features compared with an extruded rubber or rubber-like material such as an ethylene-propylene rubber conductive compound. The low coefficient of friction makes it unnecessary to use a lubricant in order to pass it through the guide tip of the second extruder. Such lubricant is commonly an oil such as dimethyl naphthalene or naphthenic petroleum oil having penetrating properties that can produce side effects such as gassing at the interface of the compounds during subsequent curing operations, or may promote an undesired softening of both compounds at the interface, and may also have a deleterious effect on physical, aging and electrical characteristics due to migration into the insulation compound. The advantages of an extruded shield in lieu of a semiconducting fabric tape are, of course, well known.

The ethylene-propylene rubber compound is advantageous because it is extremely resistant to ozone and corona discharge, and has excellent electrical insulating characteristics, and aging properties. It is flexible, and enables bending through much shorter radii than a similar cable utilizing cross-linked polyethylene as the insulation.

Unlike cross-linked polyethylene compounds which shrink considerably after curing, the ethylene-propylene rubber compound can be extruded through a die with a diameter equal to the desired diameter of the cured insulation. The lack of shrinkage of the ethylene-propylene rubber wall during and after cure, enables the concentricity and surface smoothness of the underlying strand shielding compounds to be maintained, and further does not force it into the interstices of the stranded conductor, thereby aiding in splicing and terminating operations associated with cable installations by leaving a clean, free stripped conductor.

Other objects, features and advantages of the invention will appear or be pointed out as the description proceeds.

BRIEF DESCRIPTION OF DRAWING

In the drawing, forming a part hereof, in which like reference characters indicate corresponding parts in all the views:

FIG. 1 is a sectional view of a power cable made in accordance with this invention;

FIG. 2 is a diagrammatic illustration of apparatus for making the power cable of this invention; and

FIG. 3 is a flow diagram for the method of this invention.

DESCRIPTION OF PREFERRED EMBODIMENT

FIG. 1 shows a power cable having a stranded conductor 10; a conductor shield 12; and insulation 14. This invention is concerned with the application of the shield 12 and the insulation 14 and with the combination of material used for the shield and insulation. The cable shown in FIG. 1 has insulation shielding 16 and an outer jacket 18 which may be conventional. The insulation shielding may be conducting cross-linked polyethylene, conducting polyethylene, conducting ethylene-propylene amorphous terpolymer or copolymer, conducting tapes, etc.

In the preferred method of making a cable in accordance with this invention, the conductor 10 is supplied to a strand shield extruder 22 (FIG. 2) in which the strand shield 12 is applied to the conductor 10 by an extrusion die 24.

The material used for the shield or shield layer 12 is a compound of conductive cross-linked polyethylene. This material is applied in a thin layer of between.

The strand shielding 12 cools rapidly because of its thin section and because of the heat sink effect of the conductor 10.

FIG. 2 shows a second extruder 26, arranged in tandem with the extruder 24, for extruding a layer of insulation over the shielded conductor which is indicated by the reference character 10'. The shielded conductor 10' passes from the extruder 22 to a guide tip 28 of the second extruder 26.

The low coefficient of friction of the polyethylene shield on the shielded conductor 10' makes it unnecessary to use a lubricant in order to pass the shielded conductor through the guide tip 28, as previously explained.

The extruder 26 applies the insulation 14 to the shielded conductor 10' through an extruder die 30; and the insulated conductor is indicated by the reference character 10''.

The insulation applied by the extruder 26 is a particular formulation of an ethylene-propylene rubber compound having a higher-than-normal polymer content. Ordinarily, ethylene-propylene copolymer rubber compounds designed for high-voltage service, contain about 30 to 45 percent by weight of polymer. The compound used for this invention contains approximately 48 percent of ethylene-propylene copolymer, which is amorphous, and 12 percent polyethylene homopolymer which is crystalline. However, other compounds containing as little as 51 percent or as much as 80 percent ethylene-propylene copolymer and as little as 0 percent, and as much as 49 percent polyethylene homopolymer may be used equally well for this invention. The total of polymer can be as high as 95 percent and as low as 20 percent.

The amorphous ethylene-propylene copolymer requires reinforcing filler to provide adequate physical properties, while the addition of filler actually reduces the physical properties of the polyethylene component.

In the insulating compound of this invention, however, the polyethylene does provide reinforcement and raises the physical properties to a desired level while also enhancing the electrical properties of the compound. Thus, the necessary but electrically undesirable filler is kept to a minimum, while the polymer content can be maintained at a much higher level than is generally considered processable. The balance of processing properties, desired physical strength level, and extraordinarily good electrical properties is, therefore, achieved by this invention. The insulated conductor 10' passes from the extruder 26 to a curing oven 34 in which the shielding layer and insulating layer are cured simultaneously. By use of

chemically cross-linked polyethylene as the conductor strand shield, and an ethylene propylene copolymer insulation which contains polyethylene, excellent adhesion of the shield and insulation is achieved. The lack of shrinkage of the ethylene-propylene rubber insulation during and after cure enables the concentricity and surface smoothness of the underlying strand shielding compound to be maintained and avoids forcing of the shielding compound into the interstices of stranded conductor, as previously explained.

The cocured layers of shield and insulation are chemically cross linked to one another in the oven 34 by formulating both compounds with a dicumyl peroxide curative system, or with an equivalent agent which causes both layers to cure at about the same rate. Any gasses which form at the interface of the shield and insulation as byproducts of the cure, are rapidly and readily absorbed by the ethylene-propylene rubber compound so as to produce a void-free interface. The higher-than-normal polymer content of the rubber insulation further provides for higher-than-normal reactive sites at the interface so that a strong, uniform degree of bonding is obtained along the full length of the cable.

The preferred embodiment of the invention has been illustrated and described and the invention is defined in the appended claims.

We claim:

1. An electrical cable comprising a conductor, semiconducting polydetin shield on the conductor, and insulation surrounding the shield and said insulation comprising an ethylene-propylene rubber compound containing also a polyolefin that fusion bonds to the shield.

2. The electrical cable described in claim 1 characterized by the shield being polyethylene and the ethylene-propylene rubber compound containing polyethylene that fusion bonds to the shield.

3. The electrical cable described in claim 2 characterized by the ethylene-propylene copolymer of the insulation com-

pound being amorphous and the polyethylene of the insulation being crystalline.

4. The electrical cable described in claim 1 characterized by the conductor being stranded, the shield being a smooth coating on the conductor, and the ethylene-propylene rubber compound being cured and bonded to the shield but free of radial pressure sufficient to force the shield into the interstices of the stranded conductor.

5. The electrical cable described in claim 3 characterized by the ethylene-propylene rubber compound containing approximately 20 to 80 percent by weight of ethylene-propylene copolymer and approximately 0 to 46 percent by weight of polyethylene, the balance being reinforcing and filler materials.

6. The electrical cable described in claim 5 characterized by the ethylene-propylene copolymer being approximately 48 percent of the insulation and the polyethylene being approximately 12 percent of the insulation.

7. The electrical cable described in claim 1 characterized by the conductor shield being a cross linked polyethylene having a higher softening point than that of the insulation before curing of the shield and insulation.

8. The electrical cable described in claim 1 characterized by both the shield and the insulation being circumferentially and longitudinally continuous layers extruded over the conductor and the shield, respectively.

9. The electrical cable described in claim 2 characterized by the materials for the shield and for the insulation being both formulated with a dicumyl peroxide curative system so that the shield and the insulation are cross linked to one another.

10. The electrical cable described in claim 2 characterized by an insulating shield of material from the group consisting of conducting cross linked polyethylene, conducting ethylene-propylene, and rubber.

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