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Wade

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[54] **ELECTRIC CABLE AND METHOD OF MAKING**

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[52] **U.S. Cl.**.....**174/115,** 117/75, 174/110 PM, 174/120 SC

[51] **Int. Cl.**.....**H01b 7/02,** H01b 9/02

[58] **Field of Search**..174/120 R, 120 C, 120 SC, 120 SR,174/115, 110 PM; 117/69, 72, 75; 252/63.7, 66

[56] **References Cited**

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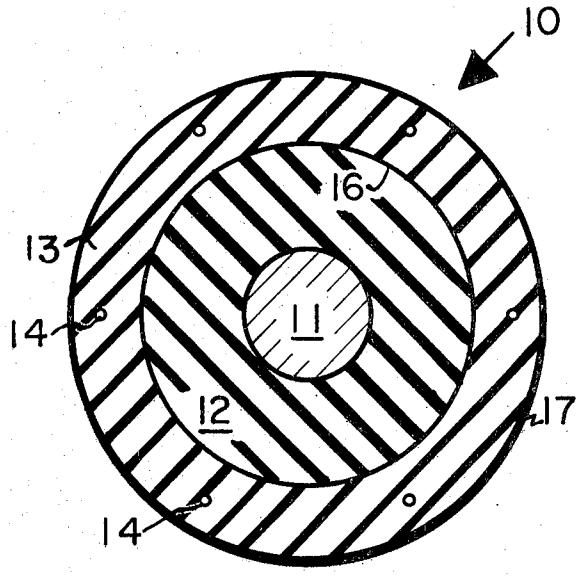
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[57] **ABSTRACT**

In an electric cable having a semiconducting jacket applied directly over a wall of polymeric insulation, excessive bonding of the jacket to the insulation is prevented by applying the curing agent for the jacket only to its outer surface after extrusion, and then effecting a vulcanization such that the inner jacket surface remains thermoplastic.

24 Claims, 2 Drawing Figures



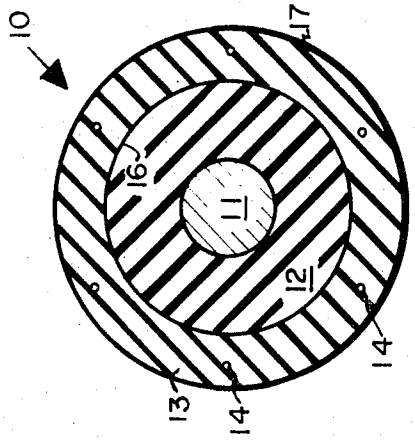


Fig. 1

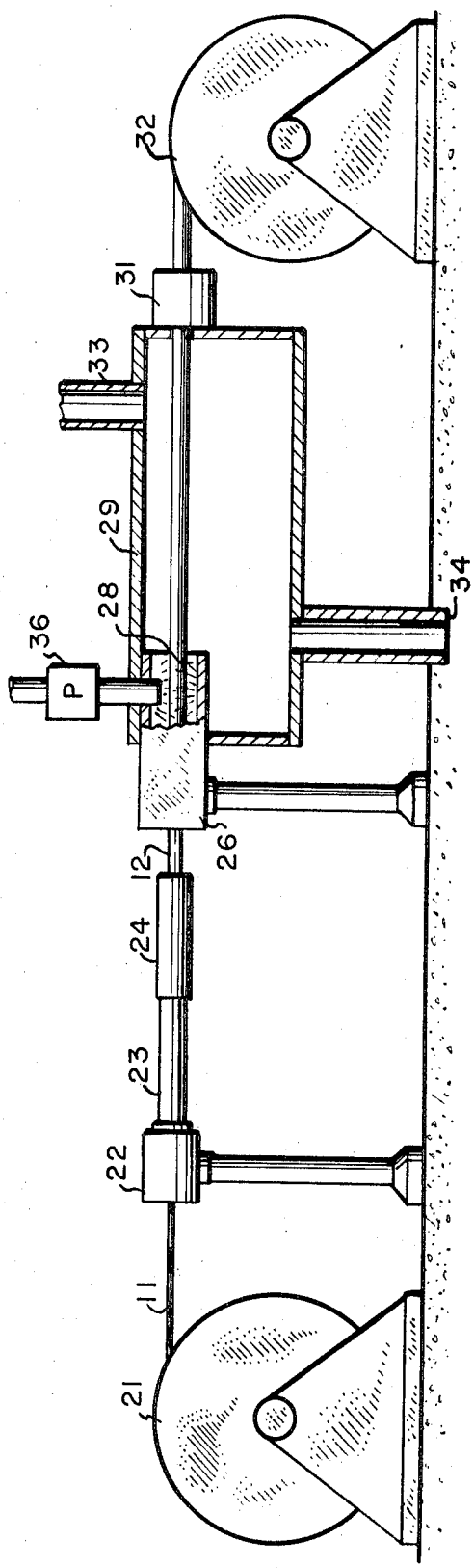


Fig. 2

ELECTRIC CABLE AND METHOD OF MAKING

BACKGROUND OF THE INVENTION

Economies in high-voltage cables have recently been effected by eliminating the separate shielding system, making the protective jacket semiconducting, and applying it directly onto the wall of cable dielectric. Such a cable construction, wherein the jacket comprises embedded drain wires is described in Plate et al. U.S. Pat. No. 3,474,189, the disclosures of which are included herein by reference. Although it would be desirable to increase the toughness and tensile strength of the jacket material by vulcanization, this has not proven feasible because of the necessity of avoiding adhesion between the semiconducting jacket and the outer surface of the wall of insulation. Such adhesion would make it difficult to free stripped ends of cable from residues of the electrically conducting jacket composition at terminations and joints.

SUMMARY

I have invented a cable and method of cable manufacture that allows the jacket of the cable to be strengthened by vulcanization without increasing its adhesion to the cable insulation. My new cable is thus provided with a jacket that can withstand the expansion of such high-thermal-coefficient insulating materials as vulcanized polyethylene, at higher cable temperatures than cables previously known. My improved cable will also more affectively resist any explusion of drain wires from cable jackets by electrical forces during high fault currents.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 shows a section of a cable made to my invention

FIG. 2 shows the steps of a method of my invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. 1, a cable of my invention, indicated generally by the numeral 10, has a conductor 11, a heavy wall 12 of insulation, and a semiconducting jacket 13 in which are embedded a plurality of drain wires 14. The wall 12 comprises cross-linked polyethylene, but my invention has application to cables with insulation walls of other compositions such, for example, as ethylene-propylene rubber, polyvinyl chloride, and unvulcanized polyolefin. However, my invention has particular advantages for cross-linked polyethylene insulated cables since cross-linked polyethylene has a particularly high thermal coefficient of expansion, and this places an extra strain on the jacket 13. The jacket 13 comprises chlorinated polyethylene blended with ethylene ethyl acrylate and a high proportion of carbon black to increase its electrical conductivity. A preferred thermoplastic jacket has been described in application Ser. No. 167,741 assigned to the assignees of the present invention, which has the advantage, that, being thermoplastic, it does not bond unduly to the wall 12. In the present invention an inner surface 16 of the jacket 13 remains thermoplastic but an outside surface 17 has been vulcanized to provide greater toughness and tensile strength. Vulcanization of the outer portion of the jacket 13 is achieved by diffusion of vulcanizing agent through the surface 17 so that the jacket 13 is homogeneous except for radial differences in the degree of vulcanization or cross linking. This vulcanization decreases gradually through a radial section of the jacket 13 so as to leave the inner surface 16 free from vulcanization. Chlorinated polyethylene has been employed in the composition of the jacket of the cable 10 principally to reduce its combustibility. However, my present invention can also be efficaciously applied to a semiconducting polyethylene jacket.

Although it will be understood that the inclusion of drain wires is not essential to the present invention, where such drain wires are included, vulcanization of the surface 17, and of a layer of the jacket surrounding the wires helps to confine the wires 14 within the jacket in two ways. The higher tensile strength of the vulcanized composition resists radial expulsion of the wires by electrical forces during surges of current, and the higher softening temperature of the vulcanized composition prevents the surface from melting during short periods of high ambient temperature.

In FIG. 2 I have diagrammed a method of making the cable 10 whereby a reel 21 of the conductor 11 is continuously paid through an extruder 22, a vulcanizing tube 23, and cooling section 24 for application of the dielectric wall 12. The insulated core then passes through a second extruder 26 wherein it receives the jacket 13 and drain wires 14.

So far the description of my method has been previously disclosed for the manufacture of cables with thermoplastic jackets. I now provide a novel step of coating the jacket 13 with a suitable curing agent by passing the cable 10 through a chamber 28 wherein it is sprayed or otherwise coated with di-α-cumyl peroxide. Although I prefer to use di-α-cumyl other peroxides are known for curing compositions comprising chlorinated polyethylene and polyethylene and these may be used within the scope of my invention, including tertiary peroxides in which the valences of the carbon atoms not linked to oxygen are attached to alkyl, cycloalkyl, alkylcycloalkyl, cycloalkyl-alkyl, aryl or aralkyl radicals, and also quinhydrone dimerides as disclosed in U.S. Pat. No. 3,036,982. Solvents other than acetone may be used, less volatile solvents having the advantage of holding the vulcanizing agent on the surface 17 through the entrance to a curing chamber. It is not essential to my invention, however, to apply the curing agent in solution. As detailed in an example hereinbelow, I have successfully applied the molten agent directly to the jacket. Curing agents can also be applied as suspensions or emulsions, such as water suspensions or emulsions.

On leaving the chamber 28 the cable 10 is passed into a vulcanizing tube 29 wherein vulcanization of the surface and diffusion of the curing agent beneath the surface is effected. Following passage through a final cooling zone 31, the cable 10 is taken up on a reel 32.

The tube 29 has a steam supply entrance 33 and a condensate drain 34 but a hot inert pressurized gas such as nitrogen or helium may be used instead of steam within the scope of my invention. The latter method has the advantage that it is easier to keep the application chamber relatively cool. To counteract the pressure in the tube 29 a pump 36 is used to meter the

vulcanizing agent into he chamber **28**. In lieu of the continuous process shown, the entire cable can be removed to a curing chamber after the surface has been coated with peroxide in solution. I have found that acetone works well as a solvent for di-α-cumyl peroxide in this application but other solvents, which have been known, can also be used.

EXAMPLE 1

A cable made in accordance with the description of FIG. **1**, hereinabove, with a jacket **13**, 0.080 inch thick was brush coated with a 50 weight percent solution of di-α-cumyl peroxide in acetone. The acetone permitted to evaporate. Thereupon the cable was vulcanized in a steam chamber at 225 pounds per square inch in pressure for one minute. Specimens cut from the outer surface of the jacket with thicknesses from 0.022–0.032 inch were found to have an average tensile strength of 1,586 psi compared to a tensile strength of 1,373 psi for an unvulcanized jacket specimen and an average elongation of 183 percent compared to 327 percent for an unvulcanized specimen.

EXAMPLE 2

A length of the cable **10** was coated with molten di-α-cumyl peroxide at 75 psi. Specimens 0.020–0.024 inch thick were sliced from the outer surface of the jacket and found to average 2,783 psi tensile strength and have 120 percent elongation. Specimens 0.018–0.020 inch thick were then sliced from the underlying thickness of jacket for testing to determine the depth of diffusion of the curing agent. These averaged 2,870 psi in tensile strength and 207 percent elongation. The much greater elongation indicates presence of some thermoplastic composition at the deeper level.

EXAMPLE 3

A cable with 250 MCM conductor, a 0.175 inch wall of cross-linked polyethylene insulation and an 0.080 inch thick chlorinated polyethylene, ethylene ethyl acrylate jacket was coated with di-α-cumyl peroxide and cured in steam at 200 psi for 1 minute. A specimen 0.015–0.020 inch thick was sliced from the outer surface of the jacket and found to have a tensile strength of 2,056 psi and an elongation of 162 percent. The conductor of a length of this cable was raised to 135°C for 24 hours to determine if the expansion of the insulation would cause cracks to appear in the jacket. No cracks appeared. The conductor temperature was raised to 155°C for 24 hours without causing any cracks to appear in the jacket. The conductor was raised to 200°C for 1 hour without causing any cracks to appear over the drain wires. A circumferential crack did appear next to a holding clamp. For comparison, cracks appeared over the drain wires of a cable with an unvulcanized jacket at a conductor temperature of 135°C after 2 hours.

I have invented a new and useful cable and method of making the same of which the foregoing description has been exemplary rather than definitive and for which I desire an award of Letters Patent as defined in the following claims.

I claim:

1. An electric cable comprising:

A. a conductor,

B. a wall of dielectric polymeric composition surrounding said conductor,

C. a jacket of polymeric composition surrounding said wall, comprising:

1. a thermoplastic inner surface directly adjacent to said wall, and

2. a vulcanized outer surface, said jacket being homogeneous save for a decreasing degree of vulcanization from said outer toward said inner surface.

2. The cable of claim **1** wherein said wall comprises polyethylene.

3. The cable of claim **1** wherein said wall comprises vulcanized polyethylene.

4. The cable of claim **1** wherein said jacket is semiconducting.

5. The cable of claim **1** wherein said jacket comprises chlorinated polyethylene.

6. The cable of claim **3** wherein said jacket comprises chlorinated polyethylene.

7. The cable of claim **4** comprising drain wires embedded within said jacket.

8. The method of making a jacketed cable comprising the steps of:

A. extruding a polymeric jacket free from vulcanizing agent around an insulated cable core,

B. applying a vulcanizing agent to the surface of said jacket, said agent being sufficient to vulcanize said surface but insufficient to vulcanize the entirety of said jacket,

C. heating said cable thereby vulcanizing said surface and diffusing said agent into said jacket.

9. The method of claim **8** wherein said vulcanizing agent is applied to said jacket in solution.

10. The method of claim **8** wherein said jacket comprises chlorinated polyethylene blended with ethylene ethyl acrylate copolymer.

11. The method of claim **8** wherein said agent comprises an organic peroxide.

12. The method of claim **8** wherein said agent comprises di-α-cumyl peroxide.

13. The method of claim **9** wherein said agent comprises di-α-cumyl peroxide.

14. The method of claim **9** wherein said solution comprises acetone and said agent comprises di-α-cumyl peroxide.

15. The method of claim **8** wherein said heating is effected under pressure.

16. The method of claim **15** wherein said heating is effected by pressurized steam.

17. The method of claim **15** wherein said agent is applied to said jacket in solution.

18. The method of claim **15** wherein said jacket comprises chlorinated polyethylene blended with ethylene ethyl acrylate copolymer.

19. The method of claim **15** wherein said agent comprises in organic peroxide.

20. The method of claim **15** wherein said agent comprises di-α-cumyl peroxide.

21. The method of claim **17** wherein said agent comprises di-α-cumyl peroxide.

22. The method of claim **17** wherein said agent comprises di-α-cumyl peroxide and said solution comprises acetone.

23. The method of claim **15** wherein said agent is applied within a chamber containing said pressure.

24. The method of claim 16 wherein said agent is applied within a chamber for said steam.

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