# United States Patent

[11] 3,589,121


[72] Inventor **Bernard J. Mulvey**
**Fairfield, Conn.**



[21] Appl. No. **846,868**
[22] Filed **Aug. 1, 1969**
[45] Patented **June 29, 1971**
[73] Assignee **General Electric Company**
Division of Ser. No. 678,920, Oct. 30, 1967, abandoned.


[54] **METHOD OF MAKING FLUID-BLOCKED STRANDED CONDUCTOR**
**4 Claims, 3 Drawing Figs.**


[52] **U.S. Cl.** ..... **57/162,** 57/149, 156/47, 156/51
[51] **Int. Cl.** ..... **H01b 13/14,** H01b 13/24, H01b 13/26
[50] **Field of Search** ..... 57/149, 145, 153, 162, 164, 7; 156/47, 48, 51—53, 412, 451



[56] **References Cited**
UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 1,610,910 | 12/1926 | Williams | 57/162 X |
| 1,610,954 | 12/1926 | Lamplough | 57/162 |
| 2,043,702 | 6/1936 | Homer | 57/162 |
| 2,093,445 | 9/1937 | Hunter | 57/162 |
| 2,427,507 | 9/1947 | Powell et al. | 57/162 X |
| 3,318,082 | 5/1967 | Riggs | 57/149 |
| 3,425,207 | 2/1969 | Campbell | 57/145 |
| 3,443,374 | 5/1969 | Carnevale | 57/149 |



*Primary Examiner*—John Petrakes
*Attorneys*—R. Jonathan Peters, Frank L. Neuhauser, Oscar B. Waddell and Joseph B. Forman



**ABSTRACT:** An insulated stranded conductor which is properly fluid blocked is manufactured by first coating a wire filament or strand, and then forming a stranded conductor with the coated filament as the center strand. An outer insulation is applied over the resulting stranded conductor under sufficient pressure to at least partially fill the interstitial spaces between the strands. The coating and insulation are formed of a curable polymeric composition, and the two materials, being in intimate contact, are cured at an elevated temperature and upon cooling, bond to each other, thereby substantially encapsulating all the strands of the conductor.

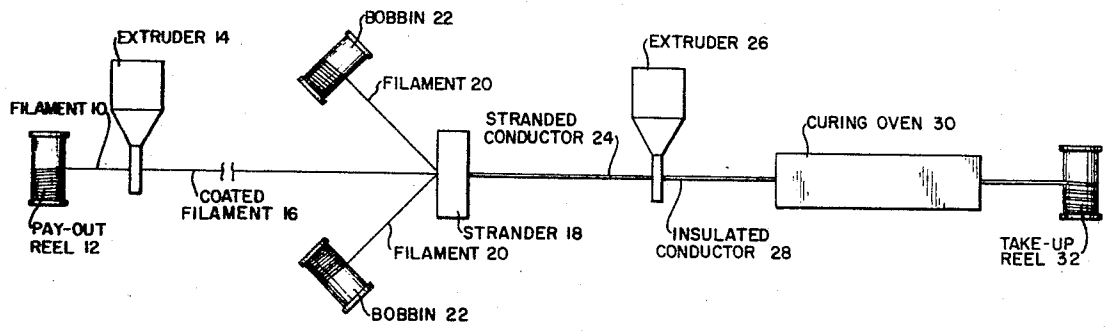



FIG. 1




FIG. 3




FIG. 2




INVENTOR.
BERNARD J. MULVEY

BY R. Jonathan Pitts

ATTORNEY

# METHOD OF MAKING FLUID-BLOCKED STRANDED CONDUCTOR

This is a division of application Ser. No. 678,920, filed Oct. 30, 1967, now abandoned.

Numerous applications frequently require cable which is substantially fluid blocked when subjected to relatively high gas or hydrostatic pressures. For example, in underwater applications control equipment or sonar equipment used by submarines and other diving vehicles are connected to the end of a cable extending from the ship's hull. The cable therefore must be watertight or water blocked so that if it is accidentally severed or damaged while under pressure, water will not enter the ship or the apparatus to which the cable is attached. Requirements for sonar cable are 1,000 p.s.i. and may be expected to go higher as deeper diving submersibles are designed. Fluid blocking is also important for deep well pump cable where the cable is run for a considerable depth into the well bore. A cut end of the cable can be subjected to gas and liquid pressures, and if the cable is properly fluid blocked so as to prevent fluid from entering the cable and causing it to expand thereby damaging the cable, part of the cable can be salvaged. A still further application is in nuclear spheres where a cable which penetrates the sphere should be leakproof against radioactive gases in the event the cable becomes damaged or cut. However, the requirements for the underwater applications are more stringent, and therefore the invention described hereinbelow is with particular emphasis to this application.

The cable typically employed for such underwater applications or the like comprises a multiple-conductor cable, and may be either shielded (i.e., coaxial) or nonshielded. The conductor is stranded in order to provide a sufficient grip between the metallic conductor and insulation and also to provide sufficient flexibility. In the multiple-conductor cable, the combination of conductors are insulated from one another, twisted and then encapsulated with a belt of substantially uniform diameter which fills the interstices between the twisted conductors. A metallic return shield, usually a tinned copper braid, may be concentrically disposed over the belt, and therefore it is important that the composition for the belt provides the proper capacitance between the conductor and the shield. The structure, with or without a metal shield, is further enclosed with a jacketing material such as styrene butadiene rubber, neoprene, or polyvinyl chloride. Where desired, the jacket may comprise tow or more layers of dissimilar materials in order to provide the proper resistance between the metallic return shield and the water.

It will be observed that the interstices in the stranded conductor provide a channel or channels for the gas or water which are difficult to block. Various strand-filling materials or water-sealing compounds are in current use such as a puttylike material known as Duxseal, depolymerized rubber, polymerizable silicone paste having a silicone oil base, and polymerizable polysulfide fluid. However, certain of these materials can be used in relatively low-pressure applications only. Moreover, if the material is not applied uniformly over the strand, open spaces between interfaces result, and consequently water leakage will occur where high pressures are encountered.

This application has therefore as its objects to provide a fluid-blocked stranded conductor which substantially inhibits the leakage of fluid along the cable if it is severed while under relatively high pressure.

In its broad aspect, the fluid-blocked stranded conductor of this invention comprises a stranded conductor with the center filament or strand coated with a polymeric composition as a strand-filling composition which partially excludes between the strands upon formation of the stranded conductor. An outer insulation of polymeric composition is formed around the stranded conductor under sufficient pressure to at least partially fill the interstitial spaces between the strands thereby contacting and forming an interface with the coating applied



to the center filament of the stranded conductor. The polymeric composition employed for the coating and insulation preferably have the same base polymer, and is selected from the group consisting of polyethylene and copolymers of ethylene containing not less than about 50 mole percent ethylene, having incorporated therein a suitable curing agent such as an organic peroxide. When the insulated stranded conductor is cured as under steam pressure, the polymer expands thereby filling still further the interstices and bringing the two materials into still closer contact. When the resulting insulated conductor is sufficiently cooled, the coating and insulation bond to each other thereby substantially blocking the conductor against leakage when a cut end of the conductor is subjected to relatively high pressures. It will be observed that a bond between the coating and insulation is essential and therefore the two materials must be compatible, because in the absence of a substantially complete bond, the pressure will separate the layer at the interface and permit the passage of fluid through the gap formed. The bond formed between the two materials may occur within the interstices or around the stranded conductor, thereby substantially encapsulating all the strands of the conductor.

In order to describe the invention in greater detail, reference is now made to the accompanying drawings, illustrating a preferred embodiment of the invention, in which:

FIG. 1 diagrammatically illustrates the process of making the cable of this invention; and accompanying

FIG. 2 is an elevational view of a cable of this invention with portions thereof cut away for the purposes of better illustrating its construction and showing the features of the invention; and

FIG. 3 is a cross section on line III–III of FIG. 2 on an enlarged scale showing the interstices filled with a polymer.

Referring to FIG. 1, a wire filament or strand **10** is passed from a payout reel **12** through an extruder or other suitable coating applicator **14** where a coating suitable as a strand-filling composition is formed over the filament. In the preferred embodiment, polyethylene having incorporated therein a suitable curing agent, is extruded over the filament but where desired a copolymer of polyethylene may be used. However, the polymeric composition is cured at a subsequent stage after the insulated stranded conductor has been completely formed. The coated filament **16** may be taken up on a reel (not shown), or, where desired passed directly to a strander **18** where additional filaments **20** passed from bobbins **22** are laid around the coated filament as the center strand. In a conventional stranded conductor, six filaments comprising the first layer surround the center filament, and each successive layer is increased by six. In general, a seven-strand conductor is employed However, where it is desirable to use a 13 -strand conductor or higher, a thicker coating over the center strand may be required, or a second coating may be applied over the inner layer or strands. The filaments are stranded under sufficient stress or pressure to form a relatively close-knit stranded conductor, and the coating applied to the center filament exudes between the strands to at least partially fill the interstices. At this stage of the operation, the stranded conductor may be taken up on a reel (not shown), or where desired the stranded conductor **24** may be passed directly through the extruder **26** where an insulation composition is extruded over the stranded conductor under sufficient pressure so that the insulation composition at least partially fills the interstices. In the preferred embodiment, this outer insulation layer comprises polyethylene having incorporated therein a suitable curing agent, but where desired a copolymer of polyethylene may be used. The insulated conductor **28** emerging from the extruder is passed through a curing oven **30** where the fabricated product is cured such as by conventional steam cure at high pressure whereby vulcanization or cross-linking of the polymer is effected. During vulcanization or curing, the two polymeric compositions expand and tend to fill the interstices between the strands. The coating composition and insulation composition are now in intimate contact, and

upon cooling bond to each other. This is more clearly illustrated in FIG. 3. The resulting insulated cable is then taken upon on reel 32.

In a conventional cable for use in underwater applications and the like, a pair of insulated stranded conductors is twisted, and subsequently provided with a ground-shielding means and suitable jacket. FIG. 2 shows such a conventional cable, and the method of manufacture for completing the cable in providing the ground-shielding means and jacket forms no part of this invention. Referring to FIG 2, there is illustrated a cable of this invention indicated generally by the numeral 34. A belt 36 is applied over the twisted pair of insulated stranded conductors 28, usually by extrusion, to fill the spaces between the twisted pair and to hold the pair in position. A metallic return shield 38 is then concentrically disposed over the belt, which is further enclosed with a suitable jacketing material. According to the embodiment illustrated, the jacketing material comprises two layers of dissimilar materials 40 and 42, such as styrene butadiene rubber and neoprene, respectively, in order to provide the proper resistance between the metallic return shield and the water.

For underwater applications such as in sonar cable, the stranded conductor may range in size from No. 18 to No. 14 AWG having diameters of 0.016 to 0.025 inch, and typically may be formed form copper, tinned copper, or aluminum, including their alloys. The coating applied over the center filament may range in thickness of from about 3 to 5 mils, but must be of sufficient thickness to provide sufficient coating to at least partially fill the interstices, but not too thick to cause oversize. The insulation layer has a nominal wall thickness of about 0.025 inch, but may vary depending upon the other design features of the overall cable.

The coating composition applied over the center strand the insulation composition over the stranded conductor comprise chemically cross-linked polyethylene or a copolymer thereof, such as ethylene-vinyl acetate containing at least 75 percent ethylene or ethylene-propylene copolymer, and preferably the two compositions have the same base polymer. Desirably the polymer has incorporated therein a suitable filler such as calcium silicate, calcined clay, alumina, carbon black, titanium dioxide, or the like, to enhance one or more physical properties. This is particularly advantageous is that not only is a good bond assured between the two compositions, but further the cured compositions in both layers are relatively more rigid than thermoplastic materials and therefore can withstand relatively high gas or hydrostatic pressures.

In preparing the insulation composition, the polymer and other additives such as antioxidant and filler are compounded or intimately admixed as in a Banbury. A suitable curing agent, desirably a tertiary peroxide or diperoxide, is then incorporated into the admixture to effect cross-linking of the polymer upon curing. A particularly suitable curing agent is di-α-cumyl peroxide, which is used in the range of about 0.5 to 10 parts by weight peroxide to 100 parts of polymer, and usually in the order of three to four parts peroxide. The compounding operation containing the curing agent is conducted within a temperature range high enough to render the composition sufficiently plastic to work but below the reacting temperature or decomposition temperature of the curing agent so that substantially little or no decomposition of the curing agent occurs during a normal cycle. The resulting compounded admixture is subsequently fabricated as by extrusion in a continuous process onto the conductor. The fabricated product is then cured such as by conventional steam curing at about 250 p.s.i.g. and 400 to 410° F.

The invention is further illustrated in the following example wherein a pair of stranded conductors was made, each formed of seven strands of tinned copper having a nominal thickness of 0.0201 inch. A polymeric composition was prepared comprising about 62 percent by weight polyethylene, about 32 percent by weight of calcined clay filler, about 1 percent by weight 1, 2 -idhydro-2, 2, 4 -trimethylquinoline (an antioxidant) and about 2 percent by weight diα-cumyl peroxide (curing agent). A small amount ( about 3 percent by weight) of coloring agent was added to separate portion of the composition for purposes of color coding. One portion of the composition was first extruded over a copper filament having a nominal wall thickness of 0.0045 inch, and six outer strands were laid over the coated filament in the conventional manner to form the stranded conductor Two stranded conductors formed in this manner were insulated with the composition, each conductor having a different color, at a nominal wall thickness of 0.025 inch. The insulation composition was extruded using an extrusion die configuration to exert sufficient pressure so as to at least partially fill the interstices of the conductor. The two insulated conductors were then cured in a conventional steam chamber maintained at a pressure of about 250 p.s.i.g. As explained above, during curing the polymeric composition will expand and tend to fill at least partially the interstices between the surrounding six strands. At the same time, the insulation is being pressed into the same interstitial spaced by the steam pressure, and consequently the center strand coating and insulation are brought into intimate contact thereby substantially encapsulating all the strands in cross-linked polyethylene.

A completed cable having a pair of insulated stranded conductors was then constructed as shown in FIG. 2, and tested for water leakage in accordance with Military Specification MIL-C-915 B. According to this test, the cut end of a 5 -foot sample is inserted through an appropriate stuffing gland into a pressure chamber. Six inches of the cable extends into the chamber. Fifteen hundred (1,500 ) p.s.i. was applied for 2 hours, and at the end of this time there was no leakage from the exposed cable end.

I claim:

1. A method of manufacturing a stranded conductor comprising:

extruding a coating around a filament; forming a stranded conductor with the coated filament as the center strand; extruding an outer insulation around the resulting stranded conductor under sufficient pressure to at least partially fill the interstitial spaced between the strands; said coating and said insulation comprising a polymer selected from the group consisting of (a) polyethylene and (b) copolymers of ethylene and other polymerizable materials, and having a curing agent incorporated therein; and curing the polymer at an elevated temperature whereby said coating and said insulation being in intimate contact are substantially bonded upon cooling and thereby substantially encapsulating all the strands of said conductor to form a conductor which substantially inhibits leakage of fluid along the conductor when a cut end of the conductor is subjected to relatively high pressure.

2. A method according to claim 1 wherein said outer insulation and said coating comprise cross-linked polyethylene.

3. The method according to claim 1 wherein a plurality of the resulting stranded conductors are incorporated into an insulated electrical cable including a belt applied around said conductors and a jacket disposed over said belt.

4. The method according to claim 3 and including arranging a metal shield between said belt and said jacket.

70

75