



Description

This invention relates to armored cables. More specifically, this invention relates to armored optical fiber cables.

Conventional electromechanical cables for oil well logging include insulated metal conductors for the transmission of electrical signals. Such cables have signal transmission bandwidths that are limited to about 100 KHz over lengths that correspond to typical depths of oil wells, 12,000 to 20,000 feet (3657.6 to 6096 m). Much of the information that is obtainable with modern logging tools is not retrievable from down the well bore due to the restricted signal bandwidth that is characteristic of state-of-the-art conventional logging cables. Consequently, a need exists to provide oil well logging cables that have substantially higher signal transmission bandwidths. Optical fibers can provide signal transmission bandwidths one to three orders magnitude higher than the insulated wires that are used in conventional well logging cables.

Glass optical fibers have two properties which make it difficult to successfully incorporate them into strain cables. These properties are static fatigue degradation and microbending loss.

Silica glass fibers have small cracks (microcracks) on their surface. The depth of these microcracks can increase through a stress-accelerated chemical reaction between the silica glass and moisture, called static fatigue. The tensile strength of the glass fiber decreases substantially as the microcracks increase in depth. Glass is an elastic material with a high Young's modulus. Strain in a glass optical fiber generates tensile stress and results in static fatigue. Thus, glass optical fibers are not suitable for use under high strain (>0.5%) in the presence of moisture over extended periods of time.

Optical fibers transmit light signals by the principle of total internal reflection. This principal depends upon the light rays being totally reflected back into the core region each time they impinge upon the core to cladding interface of the optical fiber.

Total internal reflection can only occur when the angle of incidence between the rays and the core to cladding interface is below a certain critical value. Bending of an optical fiber causes some of the light which is propagating in the fiber core to impinge upon the core to cladding interface at angles of incidence greater than the minimum value and to be refracted out of the optical core and lost. The amount of the light that is lost becomes greater as the effective diameter of the bend becomes smaller. When the bending of the optical fiber is caused by deflection due to local lateral forces, the resulting decrease in signal strength is called microbending loss. When an optical fiber is deflected by a local inhomogeneity, such as a lump in its coating layers, the effective diameter of the bend depends upon the local strain the fiber is under. Generally, the fiber will bend to a smaller effective diameter

as the strain level it is under increases. Consequently, higher strain levels result in higher levels of microbending loss.

A necessary condition for accurate logging of a well bore is an accurate knowledge of the position of the logging tool within the well bore. The position of the tool is defined by the actual length of logging cable that is suspended in the well bore. The actual length of suspended cable can be determined from a knowledge of the amount of unstressed cable length that has been lowered into the well plus a knowledge of the elongation versus tension characteristics of the cable and the tension along the suspended cable length. The amount of unstressed cable length that has been lowered into the well bore can be precisely measured. The tension profile along the suspended length of cable can be accurately determined if the elongation versus tension characteristics of the cable are accurately known and are repeatable.

Conventional electromechanical cables for well logging can be constructed to withstand harsh high temperature environments and to accept high levels of axial strain while still remaining functional. More specifically, for example, each conductor element in a conventional logging cable comprises a bundle of copper wires. The copper wires yield inelastically at low strain. When the cable is alternately stretched and relaxed, the copper does not fully return to its original state and eventually the copper wires become brittle, due to strain hardening, and break. However, even this serious condition does not necessarily render the cable inoperable because a break in one or more wires with adjacent nonbroken wires permits the current to be passed to the neighbouring wires and thus the conductor still appears whole and the cable remains functional. Thus, conventional logging cables can withstand considerable inelastic and elastic strain and still remain functional.

Well logging cables are generally constructed with two layers of external steel armor wires, see for example GB-A-2036361 (or also GB-A-1598540 or GB-A-1598438). The armor wires are preformed and applied in helices of opposing handedness to prevent the cable from unwinding when supporting a free hanging load. Inside the armored jacket can be seven insulated copper conductors laid six around one in helices generally of opposite handedness to those of the steel wires in the inner armor layer. However, there is no definite relationship between the helices of the copper conductors and those of the inner armor wires since they are added in separate fabrication steps and usually with a bedding layer of a pliant material therebetween. A result of this conventional cabling geometry is that the interface between the inner armor wires and the underlying insulated conductors consists of a multiplicity of cross-over points separated by the pliant bedding material.

When a conventional well logging cable is tensioned at elevated temperatures, it will elongate

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gate by an amount which is not accurately predictable. This is because the elongation consists of two parts, one that is linear and one that is highly nonlinear and inelastic. The inelastic part occurs because the armor wires inelastically deform the underlying compliant bedding and the wire insulation, due to very high local stresses at the crossover points, and take on a smaller pitch diameter. The inelastic part of the cable elongation is not very predictable or repeatable and consequently the position of the logging probe will not be accurately known.

In order to prevent inelastic strain from occurring in use, conventional logging cables are given a hot prestretch during fabrication. When properly conducted, the hot prestretch operation will result in a cable that exhibits a linear and elastic elongation in response to tension. The hot prestretching operation imparts a permanent (inelastic) strain of between 3/4 to 1 1/2 percent to conventional seven-conductor logging cables. Hot prestretching of a conventionally designed armored cable containing one or more optical fibers within its core would leave the glass optical fibers under a permanent elongation of 3/4 to 1 1/2 percent. Optical fibers in cable subjected to these high permanent strain levels would soon fail from static fatigue and/or exhibit intolerably high microbending losses. It is apparent that conventional prestretching technology cannot be applied to armored optical fiber cables. Thus, it would be highly desirable to have an armored fiber optical cable which overcomes these and other difficulties and permits the expansion of optical fiber communications technology into areas of harsh environments.

According to one aspect of the present invention, there is provided an armored optical fiber cable having a substantially non-deformable central core element, a layer of substantially solid insulated conductor elements helically wound around said central core element in a given handedness and lay length, and an armored jacket comprising an inner layer and an outer layer of armor wires helically wound around said layer of conductor elements, the armor wires of the outer layer being helically wound in an opposite helical handedness to that of the armor wires of the inner layer such that the torques exerted by said inner armor wires and said outer armor wires are substantially balanced, and the central core element, conductor elements and inner armor layer wires forming a central bundle through which extends longitudinally at least one jacketed optical fiber, characterized in that the inner layer of armor wires is wound around the layer of conductor elements in a unilay helical configuration, in the same handedness and the same lay length as that of said layer of conductor elements and the inner layer armor wires each rest on an adjacent conductor element and not in the grooves formed between adjacent conductor elements, whereby there are no crossover points between the conductor elements and the inner armor layer wires, such mutual arrangement

between said layer of conductor elements and said inner layer of armor wires being obtainable by assembling both layers around the central core element in the same operation.

According to another aspect of the invention, there is provided a method of forming such an armored optical fiber cable which method comprises:

winding a plurality of insulated conductor elements helically around a central core element, said winding being of a given handedness and lay length;

winding a layer of a plurality of inner armor wires, of the same handedness as said conductor elements and with the same lay length and applied at the same time as said conductor elements helically around and contacting said conductor elements wherein at least one jacketed optical fibre is longitudinally provided through the central bundle formed of said central core element, said conductor elements and said inner armor wires; and

fabricating a layer of outer armor wires contacting said layer of inner armor wires and of opposite handedness to said layer of inner armor wires and with a lay length such that the torques exerted by said inner and outer armor wires are substantially balanced when the cable is under tension.

The cable and method of fabrication of the invention minimizes the inelastic part of the cable elongation by minimizing the deformability of the core. The central bundle of the cable comprises at least two inner layers, including the inner armor, which are stranded in a "unilay" configuration of a given handedness around a central element. A "unilay" configuration is defined as a cable bundle wherein the element is in continuous contact with, and in the same orientation with respect to its nearest neighbors. The central bundle contains at least one optical fiber. The cross-sections of the central bundle are identical at every point along the cable, except for a rotation about the central axis. The unilay construction distributes the transverse forces continuously along the touching components instead of concentrating the forces at crossover points as in contrahelically formed layers of cable elements or layers of unidirectionally cabled elements that have different lay lengths. The lay length of the cable is long, of the order of about 3.5 inches (8.89 cm) for a cable with an outside diameter of about 0.5 inch (1.27 cm). "Lay length" is defined as the distance along the cable or helical axis traversed by one complete helical revolution of the element. The cable has at least one outer armor layer which is contrahelically wound around the central bundle. The outer armor layer is of opposite handedness to the central bundle and substantially balances the torque of the inner armor when the cable is under tension. The elements of the layers are hard and resistant to deformation. This means that any conductor elements contained in the cable are single metal conductors and not multifilament conductors.

The layers in the central bundle are fabricated in a single operation with the same lay length and with the same handedness. The outer armored layer of opposite handedness is applied directly over the central bundle.

Reference will now be made, by way of example, to the accompanying drawing in which:

Figure 1 illustrates a cross-sectional view of an armored optical fiber cable.

In Figure 1 there is illustrated an armored optical cable 10 of the invention. The armored optical cable 10 will be described with respect to specific parameters such as overall size, dimensions and materials used to fabricate a well logging cable which comes within the scope of the invention. However, the invention is not intended to be limited solely to the specific dimensions or materials used in the description nor to only well-logging applications. The described cable is useful in any application which requires minimum cable deformations under load.

The armored optical cable 10 has a central core 12. The central core 12 has an outer diameter of about 0.120 inches (0.3050 cm) $\pm 1\%$. The central core comprises one or a plurality of optical fibers 14. The optical fibers 14 can be single-mode or multimode fibers, or mixtures thereof. The optical fibers are surrounded by a cushioning material such as an elastomeric cushioning material, for example, silicon elastomers and the like. If the central core comprises a plurality of optical fibers, the optical fibers should preferably be stranded together with the same helical handedness as the elements 22 and the inner armor wires 24 of the central bundle 30. For example, the three fibers illustrated have a right-handed lay sense and about 3.5 inch (8.89 cm) lay length (1.2° lay angle). In the illustrated embodiment, the three-fiber assembly is embedded in and surrounded with a compliant, resilient material 16 such as silicone RTV. The coated fibers are further coated with a hard, stiff jacket 18 of a material such as a fiberglass-epoxy matrix. The jacket 18 has an outer diameter of about 0.094 inches (0.239 cm) $\pm 2\%$. A suitable glass-epoxy jacket material is fabricated under the name of Stratoglas®, a product of the Air Logistics Corporation of Pasadena, California.

Surrounding the hard, stiff jacket 18 is an outer jacket 20 of material such as polyvinylidene (Kynar®, a product of the Pennwalt Company), perfluoroalkoxy (PFA Teflon®, a product of ICI), or similar material. The outer jacket 20 should be of a sufficient thickness so that the central core 12 has the appropriate outer diameter of about 0.120 inches (0.305 cm) $\pm 1\%$.

Alternatively, the cable 10 would have a central core 12 of a gas pressure tight type cable of the appropriate diameter illustrated in U.S.—A—4,312,565. Another alternative is to have a central metal tube of the appropriate diameter with one or more optical fibers therein. One such optical fiber tube is described in our copending European Application EP—A—83902789.3 (Publication Number WO 84/00820 or EP—A—0.116.619).

In the preferred embodiment, the space for the

central core 12 is formed by at least six elements 22, such as conductor strands, layed around the central core 12 with a right-handed lay sense and a 3.5 inch (8.89 cm) lay length (9.8° lay angle). To obtain a larger diameter for the central core 12, more conductor strands, e.g. eight, as illustrated, are used to fabricate the space for the central core 12. The conductor strands 22 should be fabricated from material which minimizes deformation and is capable of interlocking with the inner armor 24. Suitable conductor strands are solid copper-plated steel wire having a diameter of about 0.0403 inch (0.1024 cm) $\pm 1\%$. The conductor strands should have a minimum conductivity of 60% minimum of International Annealed Copper Standard (ICAS) with a yield strain of about 0.9% minimum at 0.2% offset. A material meeting these requirements is Copperweld®. The solid copper-plated steel wire is coated with an insulator such as Kynar® to an outer diameter of about 0.071 inches (0.180 cm). The central core 12 and the conductor strands 22 should have a combined outer diameter of about 0.262 inches (0.665 cm).

An alternative embodiment is to fabricate the cable with a solid central core 12 having about 0.120 inches (0.305 cm) O.D. $\pm 1\%$ with a conductivity of 30% minimum of ICAS, and a yield strain of about 0.9% minimum at 0.2% offset. In this embodiment, the elements 22 contain several central optical fibers surround with a suitable protective jacket. A suitable element 22 has a central optical fiber with about a 125 micron diameter with the silicon RTV coating it to a thickness of about 325 microns O.D. and with a Hytrel®, a product of Du Pont, coating to an O.D. of about 500 microns $\pm 5\%$. A suitable glass optical fiber meeting these requirements can be purchased from ITT Corporation. A glass-epoxy matrix is applied over this optical fiber to an O.D. of about 0.040 inches (0.102 cm) $\pm 2\%$ and Kynar® or other suitable coating is applied over the glass-epoxy matrix to an O.D. of about 0.071 inches (0.180 cm) $\pm 1\%$. Assuming eight elements 22, up to three of the elements would be the optical fibers and the other elements are conductor strands such as Copperweld®. Preferably, the optical fibers are integrated among the eight elements.

Inner armor wires 24 surround the conductor strands 22 there being at least twice the number of inner armor wires as there are conductor strands. In this preferred embodiment, sixteen inner armor wires 24 should be of a drawn, galvanized, improved plow steel rope wires (AISI) or other suitable material with a diameter of about 0.0575 inches (0.1461 cm) $\pm 1\%$, minimum tensile strength of about 244 KPSI (1.68 GPa) minimum torsions (8") (20.3 cm) of about 39, a coating adherence as evidenced by a 3D mandrel wrap test. The inner armor wires 24 are layed as part of the central bundle 30 with a right-handed lay sense and a 3.5 inch (8.89 cm) lay length (15.5° lay angle). The central bundle 30 has an outside diameter of about 0.368 inches (0.935 cm). It is important that the sixteen inner armor wires 24 be electro-galvanized with bright and smooth finishes such

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as a minimum zinc coating of about 0.2 oz/ft² (61.03 g/m²). The inner armor wires 24 lie adjacent to the insulated conductors 22 and hence must provide a smooth interface for transferring compressive loads to the insulated wires.

A suitable protective material 26 for the intended environment of the cable 10 is applied during the fabrication of the central bundle 30 out to the inner armor 24. Suitable materials for a well logging cable are nitrile rubber based filling compounds and the like. The inner armor wires 24 are wound around the conductor strands 22 as illustrated to provide room for eight interstitial elements 28. The eight interstitial elements 28 are optional and can be either a corrosion inhibitor lubricant 26, such as TMS 5878 Compound, a product of Quaker Chemical Company, or wires or insulated conductors or jacketed optical fibers. The interstitial elements 28 are layed with the same lay sense as conductor strands 22 and inner armor wires 24. The interstitial elements 28 are cabled with a right-handed lay sense and 3.5 inch (8.89 cm) lay length (12.5° lay angle). The interstitial elements 28 must have a maximum outside diameter of about 0.028 inches (0.071 cm) minimum zinc coating of about 0.1 oz/ft² (30.52 g/m²), minimum tensile strength of about 251 KPSI (1.73 GPa), minimum torsions (8'') (20.3 cm) of about 83, and a coating adherence as evidenced by 2D mandrel wrap test. If the interstitial elements 28 are used to control the placement of the inner armor wires 24, then the elements 28 should preferably be solid, bright, galvanized wires. It is important that any interstitial elements 28 have a rounded and smooth external surface since they lie adjacent to the insulated conductor strands and must provide a smooth surface for transferring compressive loads to the insulated strands.

A unique feature of the armored optical cable 10 is the fact that the elements of the central bundle 30 are fabricated with the same lay length and handedness so that they nestle together and do not crossover each other. Another unique feature is the fact that the conductor strands 22 and the inner armor wires 24 are assembled in the same operation so that the elements 22 and 24 rest on each other and not in the grooves formed between the conductor strands 22. This construction gives the cable greater flexibility and reduces friction between the conductor strands 22 and the inner armor wires 24. These features provide for minimal deformation of the interface between the elements and hence minimal inelastic elongation of the cable.

Surrounding the inner armor wires 24 and forming the outside diameter of the cable 10 is at least one layer of outer armor wires. Illustrated in the preferred embodiment are twenty-four strands of outer armor wires 32. The outer armor wires 32 should be fabricated from galvanized, improved plow steel rope wires (AISI) or other suitable materials having about a 0.049 inch (0.124 cm) diameter $\pm 1\%$, minimum zinc coating of about 0.4 oz/ft² (122.065 g/m²), test per ASTM A-90, minimum tensile strength of about 246

KPSI (1.70 GPa), test per ASTM E-8, minimum torsions (8'') (20.3 cm) of about 47, test per FED SPEC RR-W-410, and an adherence coating meeting ASTM A-641 using a 3D mandrel. The wires 32 are preferably preformed and layed with a lay sense opposite that of elements 22 and 24. For this example, the lay handedness of the outer armor wires 32 should be a left-handed lay sense and a 3.5 inch (8.89 cm) lay length (20.5° lay angle). As the outer armor wires 32 are being applied, the central bundle 30 is coated with a corrosion-resistant and lubricating material 34 such as TMS 5878, and the like. The overall dimensions of the optical cable 10 will be about 0.469 inches (1.191 cm).

The preferred armored optical cable 10 described herein is fabricated in one in-line operation. The central bundle 30 is formed from one bay of planetary bobbins and the outer armor wires 32 are applied directly over the central bundle 30 from a tandem bay of planetary bobbins. The outer armor wires 32 are applied in an opposite handedness such that the torques exerted by said inner and outer armor wires are substantially balanced. A suitable method for balancing the contrahelically wound outer armor wires 32 and the inner armor wires 24 is disclosed in U.S. Patent No. 4,317,000. The machines which fabricate the cable of the invention are known in the art as planetary cabling machines. A suitable source for the fabrication of the cable is Blake Wire and Cable Company of Torrance, California. Of course, the cable can also be fabricated by a tube winder cabling machine; however, the outer armor wires will have to be applied in a separate step.

Having described the invention with respect to a particularly preferred embodiment and some preferred alternatives, it should be understood that the invention is not intended to be limited solely to the description therein. Modifications which would be obvious are intended to be within the scope of the invention. For example, the cable is not limited to any specific diameter, number of optical fibers, and the like. A different environment or job application which required a larger load placed on the cable could require a larger diameter cable with larger and/or more conductor strands, inner armor wires or outer armor wires. In addition, the lay length must be increased, in direct proportion, as the diameter of the cable increases. Furthermore, it is necessary that the conductor strands and the inner armor are fabricated in one operation with the same handedness and the inner armor is set up so as not to lie in the grooves formed by the conductor strands. The outer armor must be wound in opposite handedness to the inner armor and of sufficient compressive strength such that the inner armor and the outer armor are substantially torque balanced.

Claims

1. An armored optical fiber cable (10) having a

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as a minimum zinc coating of about 0.2 oz/ft² (61.03 g/m²). The inner armor wires 24 lie adjacent to the insulated conductors 22 and hence must provide a smooth interface for transferring compressive loads to the insulated wires.

A suitable protective material 26 for the intended environment of the cable 10 is applied during the fabrication of the central bundle 30 out to the inner armor 24. Suitable materials for a well logging cable are nitrile rubber based filling compounds and the like. The inner armor wires 24 are wound around the conductor strands 22 as illustrated to provide room for eight interstitial elements 28. The eight interstitial elements 28 are optional and can be either a corrosion inhibitor lubricant 26, such as TMS 5878 Compound, a product of Quaker Chemical Company, or wires or insulated conductors or jacketed optical fibers. The interstitial elements 28 are laid with the same lay sense as conductor strands 22 and inner armor wires 24. The interstitial elements 28 are cabled with a right-handed lay sense and 3.5 inch (8.89 cm) lay length (12.5° lay angle). The interstitial elements 28 must have a maximum outside diameter of about 0.028 inches (0.071 cm) minimum zinc coating of about 0.1 oz/ft² (30.52 g/m²), minimum tensile strength of about 251 KPSI (1.73 GPa), minimum torsions (8'') (20.3 cm) of about 83, and a coating adherence as evidenced by 2D mandrel wrap test. If the interstitial elements 28 are used to control the placement of the inner armor wires 24, then the elements 28 should preferably be solid, bright, galvanized wires. It is important that any interstitial elements 28 have a rounded and smooth external surface since they lie adjacent to the insulated conductor strands and must provide a smooth surface for transferring compressive loads to the insulated strands.

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KPSI (1.70 GPa), test per ASTM E-8, minimum torsions (8'') (20.3 cm) of about 47, test per FED SPEC RR-W-410, and an adherence coating meeting ASTM A-641 using a 3D mandrel. The wires 32 are preferably preformed and laid with a lay sense opposite that of elements 22 and 24. For this example, the lay handedness of the outer armor wires 32 should be a left-handed lay sense and a 3.5 inch (8.89 cm) lay length (20.5° lay angle). As the outer armor wires 32 are being applied, the central bundle 30 is coated with a corrosion-resistant and lubricating material 34 such as TMS 5878, and the like. The overall dimensions of the optical cable 10 will be about 0.469 inches (1.191 cm).

The preferred armored optical cable 10 described herein is fabricated in one in-line operation. The central bundle 30 is formed from one bay of planetary bobbins and the outer armor wires 32 are applied directly over the central bundle 30 from a tandem bay of planetary bobbins. The outer armor wires 32 are applied in an opposite handedness such that the torques exerted by said inner and outer armor wires are substantially balanced. A suitable method for balancing the contrahelically wound outer armor wires 32 and the inner armor wires 24 is disclosed in U.S. Patent No. 4,317,000. The machines which fabricate the cable of the invention are known in the art as planetary cabling machines. A suitable source for the fabrication of the cable is Blake Wire and Cable Company of Torrance, California. Of course, the cable can also be fabricated by a tube winder cabling machine; however, the outer armor wires will have to be applied in a separate step.

Having described the invention with respect to a particularly preferred embodiment and some preferred alternatives, it should be understood that the invention is not intended to be limited solely to the description therein. Modifications which would be obvious are intended to be within the scope of the invention. For example, the cable is not limited to any specific diameter, number of optical fibers, and the like. A different environment or job application which required a larger load placed on the cable could require a larger diameter cable with larger and/or more conductor strands, inner armor wires or outer armor wires. In addition, the lay length must be increased, in direct proportion, as the diameter of the cable increases. Furthermore, it is necessary that the conductor strands and the inner armor are fabricated in one operation with the same handedness and the inner armor is set up so as not to lie in the grooves formed by the conductor strands. The outer armor must be wound in opposite handedness to the inner armor and of sufficient compressive strength such that the inner armor and the outer armor are substantially torque balanced.

Claims

1. An armored optical fiber cable (10) having a



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substantially non-deformable central core element (12), a layer of substantially solid insulated conductor elements (22) helically wound around said central core element (12) in a given handedness and lay length, and an armored jacket comprising an inner layer (24) and an outer layer (32) of armor wires helically wound around said layer of conductor elements (22), the armor wires (32) of the outer layer being helically wound in an opposite helical handedness to that of the armor wires (24) of the inner layer such that the torques exerted by said inner armor wires (24) and said outer armor wires (22) are substantially balanced, and the central core element (12), conductor elements (22) and inner armor layer wires (24) forming a central bundle (30) through which extends longitudinally at least one jacketed optical fiber (14), characterized in that the inner layer of armor wires (24) is wound around the layer of conductor elements (22) in a unilay helical configuration, in the same handedness and the same lay length as that of said layer of conductor elements (22), and the inner layer armor wires (24) each rest on an adjacent conductor element (22) and not in the grooves formed between adjacent conductor elements, whereby there are no crossover points between the conductor elements (22) and the inner armor layer wires (24), such mutual arrangement between said layer of conductor elements (22) and said inner layer of armor wires (24) being obtainable by assembling both layers around the central core element in the same operation.

2. A cable according to Claim 1, wherein the layer of conductor elements (22) is composed of at least six conductor elements (22), and the inner layer of armor wires (24) is composed of at least twice the number of conductor elements (22).

3. A cable according to Claim 1 or 2, wherein the central core element (12) comprises a plurality of helically wound optical fibers (14) embedded in a cushioning material (16) and coated with a jacket (20) of a hard resilient material.

4. A cable according to Claim 3, wherein the hard, resilient material is selected from the group consisting of polyvinylidene, perfluoroalkoxy and polyetheretherketone.

5. A cable according to Claim 3, wherein the hard, resilient material (20) is polyvinylidene extruded over a glass-epoxy layer (18) coating the optical fibers (14) embedded in said cushioning material (16).

6. A cable according to any one of Claims 1 or 5, wherein the conductor elements (22) are conductor strands of a copper-plated steel wire conductor.

7. A cable according to Claim 6, wherein the inner armor layer wires (24) consist of galvanized steel wire.

8. A cable according to Claim 7, wherein the conductor strands (22) and the inner armor wires (24) form interstitial spaces (28) which are occupied by jacketed optical fibers, or galvanized steel wire fillers.

9. A cable according to Claim 8, wherein the

outer armor layer wires (32) are galvanized, pre-formed plough steel wires.

10. A cable according to any preceding claim, wherein the central core (12), conductor elements (22) and inner armor wires (24) are coated with a nitrile rubber based filling compound (26).

11. A cable according to Claim 1 or 2, wherein the central core (12) is a solid wire, and there are from one to three jacketed optical fibers interspaced among the conductor elements (22), which are insulated copper-plated steel wire conductors, there being a total of eight conductor elements and optical fibers.

12. An armored optical cable according to Claim 2, comprising:

a substantially non-deformable and round central core element (12) having an outer diameter of about 0.120 inches (0.305 cm), said core element (12) comprising a plurality of optical fibers (14) embedded in elastomer (16) and coated with a hard, resilient material (20);

eight substantially round and solid insulated conductor strands (22) wound around and contacting said central core (12) with a right hand lay and about a 3.5 inch (8.89 cm) lay length and a diameter of 0.071 inches (0.180 cm) such that the outer diameter of the central core and the conductor strands is about 0.262 inches (0.655 cm);

sixteen substantially round inner armor wires (24) of galvanized steel wire having an outer diameter of about 0.058 inches (0.147 cm) wound around and contacting said conductor strands (22) in the same handedness and lay length as said conductor strands, wherein said central core elements (12), said conductor strands (22) and said inner armor wires (24) form a central bundle (30) having an outer diameter of about 0.368 inches (0.935 cm); and

twenty-four substantially round outer armor wires (32) of galvanized steel wire wound around and contacting said sixteen inner armor wires (24) in a left hand lay with a 3.5 inch (8.89 cm) lay length, said outer armor wires having a diameter of about 0.049 inches (0.124) such that the total cable diameter has an outside diameter of about 0.469 inches (1.191 cm).

13. A cable according to Claim 12, wherein the central bundle (30) is filled with an elastomeric filling compound (26).

14. A cable according to Claim 13, wherein the interstices formed between said inner armor strands and outer armor strands are filled with a corrosion inhibitor and lubricant (34).

15. A method of forming an armored optical fiber cable (10) in accordance with Claim 1, which method comprises:

winding a plurality of insulated conductor elements (22) helically around a central core element (12), said winding being of a given handedness and lay length;

winding a layer of a plurality of inner armor wires (24), of the same handedness as said conductor elements (22) and with the same lay length and applied at the same time as the said conductor elements helically around and contact-



ing said conductor elements (22), wherein at least one jacketed optical fiber (14) is longitudinally provided through the central bundle (30) formed of said central core element, said conductor elements and said inner armor wires; and

fabricating a layer of outer armor wires (32) contacting said layer of inner armor wires (24) and of opposite handedness to said layer of inner armor wires and with a lay length such that the torques exerted by said inner and outer armor wires are substantially balanced when the cable is under tension.

16. A method according to claim 15, wherein the method further comprises laying down interstitial elements (28) in the interstitial space formed between said conductor elements (22) and said inner layer of armor wires (24) at the same time as said conductor elements and said inner layer of armor wires are being formed.

Patentansprüche

1. Verstärktes faseroptisches Kabel (10) mit einem im wesentlichen nicht verformbaren mittigen Kernelement (12), einer Lage im wesentlichen fester isolierter Leiterelemente (22), die spiralförmig um dieses mittige Kernelement (12) in einem gegebenen Sinn bzw. einem gegebenen Aufbau oder einer solchen Lagenlänge gewickelt sind, einem verstärkten Mantel mit einer Innenlage (24) und einer äußeren Lage (32) von Verstärkungsdrähten, die spiralförmig um diese Lage von Leiterelementen (22) gewickelt sind, wobei die Verstärkungsdrähte (32) der äußeren Lage spiralförmig in entgegengesetztem Spiralsinn bzw. gemäß entgegengesetztem Aufbau zu dem der Verstärkungsdrähte (24) der inneren Lage derart gewickelt sind, daß die durch diese inneren Verstärkungsdrähte (24) und diese äußeren Verstärkungsdrähte (32) ausgeübten Verdrehungsmomente im wesentlichen ausgeglichen werden und das mittige Kernelement (12), die Leiterelemente (22) sowie die inneren Lagen von Verstärkungsdrähten (24) ein mittiges Bündel (30) bilden, durch welches in Längsrichtung wenigstens eine ummantelte optische Faser (14) sich erstreckt, dadurch gekennzeichnet, daß die innere Lage von Verstärkungsdrähten (24) um die Lage von Leiterelementen (22) in einer einlagigen spiralförmigen Konfiguration in gleichem Sinne bzw. in gleichem Aufbau und der gleichen Lagenlänge wie die dieser Lage von Leiterelementen (22) gewickelt ist und daß die inneren Lagen von Verstärkungsdrähten (24) jede auf einem benachbarten Leiterelement (22) und nicht in den Nuten ruhen, die zwischen benachbarten Leiterelementen ausgebildet sind, derart, daß keine Überkreuzungspunkte zwischen den Leiterelementen (22) und den Lagen von inneren Verstärkungsdrähten (24) sich erstrecken, wobei diese gegenseitige Anordnung zwischen dieser Lage von Leiterelementen (22) und dieser inneren Lage von Verstärkungsdrähten (24) erreichbar ist, indem beide Lagen um das mittige Kerne-

lement im gleichen Vorgang herum zusammengefügt werden.

2. Kabel nach Anspruch 1, dadurch gekennzeichnet, daß die Lage von Leiterelementen (22) zusammengesetzt ist aus wenigstens sechs Leiterelementen (22) und daß die innere Lage von Verstärkungsdrähten (24) zusammengesetzt ist aus wenigstens der doppelten Anzahl von Leiterelementen (22).

3. Kabel nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß das mittige Kernelement (12) eine Vielzahl von spiralförmig gewickelten optischen Fasern (14) umfaßt, die in ein Federungsmaterial (16) eingebettet und mit einem Mantel (20) aus hartem federnden Material überzogen sind.

4. Kabel nach Anspruch 3, dadurch gekennzeichnet, daß das harte federnde Material gewählt ist aus der Gruppe Polyvinyliden, Perfluoralkoxy und Polyetheretherketon.

5. Kabel nach Anspruch 3, dadurch gekennzeichnet, daß das harte federnde Material (20) Polyvinyliden ist, welches über eine Glasepoxy-schicht (18) extrudiert ist, welche die optischen in diesem federnden Material (16) eingebetteten Fasern (14) überzieht.

6. Kabel nach einem der Ansprüche 1 oder 5, dadurch gekennzeichnet, daß die Leiterelemente (22) Leiterstränge eines kupferplattierten Stahldrahtleiters sind.

7. Kabel nach Anspruch 6, dadurch gekennzeichnet, daß die inneren Verankerungsdrähte (24) aus galvanisiertem Stahlbad bestehen.

8. Kabel nach Anspruch 7, dadurch gekennzeichnet, daß die Leiterstränge (22) sowie die inneren Verstärkungsdrähte (24) Zwischenräume (28) bilden, die von ummantelten optischen Fasern oder galvanisierten Stahldrahtfüllern eingenommen sind.

9. Kabel nach Anspruch 8, dadurch gekennzeichnet, daß die äußeren Drähte der Verstärkungslagen (32) galvanisierte vorgeformte Guß- oder Patentstahldrähte sind.

10. Kabel nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß der mittige Kern (12), die Leiterelemente (22) sowie die inneren Verstärkungsdrähte (24) mit einer Füllerverbindung auf Nitrilkautschukbasis (26) überzogen sind.

11. Kabel nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß der mittige Kern (12) ein fester Kern ist und daß ein bis drei ummantelte optische Fasern vorgesehen sind, die im Zwischenraum längs der Leiterelemente (22) vorgesehen sind, welche kupferplattierte Stahldrahtleiter sind, und daß insgesamt acht Leiterelemente und optische Fasern vorgesehen sind.

12. Verstärktes faseroptisches Kabel nach Anspruch 2 umfassend:

ein im wesentlichen nicht verformbares und rundes mittiges Kernelement (12) mit einem Außendurchmesser von etwa 0,305 cm (0,120 englische Zoll), wobei dieses Kernelement (12) eine Vielzahl optischer im Elastomer (16) eingebetteter optischer Fasern (14) umfaßt, die mit



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einem harten federnden Material (20) überzogen sind;

acht im wesentlichen runde und feste isolierte Leiterstränge (22), die gewickelt sind um und kontaktieren den mittigen Kern (12) mit einer rechts gewickelten Lage bzw. einer Lage mit Aufbau im Rechtssinn und die etwa eine Lagenlänge von 8,89 cm (3,5 englische Zoll) und einen Durchmesser von 0,180 cm (0,071 englische Zoll) haben, derart, daß der äußere Durchmesser des mittigen Kerns und der Leiterstränge etwa 0,665 cm (0,262 englische Zoll) hat;

sechzehn im wesentlichen runde innere Verstärkungsdrähte (24) aus galvanisiertem Stahldraht mit einem äußeren Durchmesser von etwa 0,147 cm (0,058 englische Zoll), die um diese Leiterstränge (22) im gleichen Steigungssinn und der gleichen Lagenlänge wie diese Leiterstränge (22) gewickelt sind und diese kontaktieren, wobei diese mittigen Kernelemente (12), diese Leiterstränge und diese inneren Verstärkungsdrähte (24) ein mittiges Bündel (30) mit einem äußeren Durchmesser von etwa 0,935 cm (0,368 englische Zoll) bilden; und

vierundzwanzig im wesentlichen runde äußere Verstärkungsdrähte (32) aus galvanisiertem Stahldraht, die um diese sechzehn inneren Verstärkungsdrähte (24) gewickelt sind und diese in einem linken Steigungssinn bzw. in längsseitigem Aufbau mit einer Länge von 8,89 cm (3,5 englische Zoll) kontaktieren, wobei diese äußeren Verstärkungsdrähte einen Durchmesser von etwa 0,124 cm (0,049 englische Zoll) derart haben, daß der gesamte Kabeldurchmesser einen Außendurchmesser von etwa 1,191 cm (0,469 englische Zoll) hat.

13. Kabel nach Anspruch 12, dadurch gekennzeichnet, daß das mittige Bündel (30) mit einer elastomeren Füllermasse (26) gefüllt ist.

14. Kabel nach Anspruch 13, dadurch gekennzeichnet, daß die zwischen diesen inneren Verstärkungssträngen und den äußeren Verstärkungssträngen ausgebildeten Zwischenräume mit einem Korrosionsinhibitor und Schmiermittel (34) gefüllt sind.

15. Verfahren zum Herstellen eines verstärkten optischen Faserkabels (10) nach Anspruch 1, umfassend:

Wickeln einer Vielzahl isolierter Leiterelemente (22) spiralförmig um ein mittiges Kernelement (12), wobei dieses Wickeln von einem gegebenen Steigungssinn und einer solchen Lagenmenge ist;

Wickeln einer Lage einer Vielzahl von inneren Verstärkungsdrähten (24) vom gleichen Steigungssinn wie diese Leiterelemente (22) und mit der gleichen Lagenlänge und aufgebracht zum gleichen Zeitpunkt, wie diese Leiterelemente spiralförmig umwickelt werden und kontaktieren die Leiterelemente (22), wobei wenigstens eine ummantelte optische Faser (14) in Längsrichtung durch dieses mittige Bündel (30) vorgesehen ist, das aus diesem mittigen Kernelement, diesen Leiterelementen und diesen inneren Verstärkungsdrähten gebildet ist; und

Herstellen einer Lage äußerer Verstärkungsdrähte (32), die diese Lage von inneren Verstärkungsdrähten (24), die von entgegengesetzten Steigungssinn bzw. Aufbau wie diese Lage aus inneren Verstärkungsdrähten ist, kontaktiert werden und die über eine Lagenlänge derart verfügen, daß die durch diese inneren und äußeren Verstärkungsdrähte ausgeübten Verdrehungsmomente im wesentlichen ausgeglichen werden, wenn das Kabel unter Spannung steht.

16. Verfahren nach Anspruch 15, dadurch gekennzeichnet, daß das Verfahren weiterhin das Ablegen von Zwischenraumelementen (28) in den Zwischenraum umfaßt, der zwischen diesen Leiterelementen (22) und dieser inneren Lage der Verstärkungsdrähte (24) gebildet ist, und zwar zu dem gleichen Zeitpunkt, zu dem diese Leiterelemente und diese inneren Lagen von Verstärkungsdrähten geformt werden.

Revendications

1. Câble blindé (10) à fibres optiques ayant un élément d'âme central sensiblement non déformable (12), une couche d'éléments conducteurs isolés sensiblement solides (22) commis en hélice autour dudit élément d'âme central (12) suivant un sens et une longueur de pas donnés, et une gaine blindée comprenant une couche intérieure (24) et une couche extérieure (32) de fils de blindage commis en hélice autour de ladite couche d'éléments conducteurs (22), les fils de blindage (32) de la couche extérieure étant commis en hélice suivant un sens d'hélice opposé à celui des fils de blindage (24) de la couche intérieure afin que les couples exercés par lesdits fils de blindage intérieurs (24) et lesdits fils de blindage extérieurs (32) soient sensiblement équilibrés, et l'élément d'âme central (12), les éléments conducteurs (22) et les fils de la couche de blindage intérieure (24) formant un faisceau central (30) dans lequel s'étend longitudinalement au moins une fibre optique gainée (14), caractérisé en ce que la couche intérieure de fils de blindage (24) est commise autour de la couche d'éléments conducteurs (22) suivant une configuration hélicoïdale monocouche, de même sens et de même longueur de pas que ceux de ladite couche d'éléments conducteurs (22), et les fils de blindage de la couche intérieure (24) reposent chacun sur un élément conducteur adjacent (22) et non dans les gorges formées entre des éléments conducteurs adjacents, de manière qu'il n'y ait aucun point de croisement entre les éléments conducteurs (22) et les fils de la couche intérieure de blindage (24), un tel agencement mutuel entre ladite couche d'éléments conducteurs (22) et ladite couche intérieure de fils de blindage (24) pouvant être obtenu par l'assemblage des deux couches autour de l'élément d'âme central dans la même opération.

2. Câble selon la revendication 1, dans lequel la couche d'éléments conducteurs (22) est composée d'au moins six éléments conducteurs (22), et



la couche intérieure de fils de blindage (24) est composée d'au moins le double du nombre d'éléments conducteurs (22).

3. Câble selon la revendication 1 ou 2, dans lequel l'élément d'âme central (12) comprend plusieurs fibres optiques (14) commises en hélice, noyées dans une matière amortisseuse (16) et revêtues d'une gaine (20) de matière élastique dure.

4. Câble selon la revendication 3, dans lequel la matière élastique dure est choisie dans le groupe comprenant du polyvinylidène, un composé perfluoroalkoxylé et une polyétheréthercétone.

5. Câble selon la revendication 3, dans lequel la matière élastique dure (20) est du polyvinylidène extrudé sur une couche (18) de résine époxy et de verre enrobant les fibres optiques (14) noyées dans ladite matière amortisseuse (16).

6. Câble selon l'une quelconque des revendications 1 à 5, dans lequel les éléments conducteurs (22) sont des brins conducteurs d'un conducteur en fil d'acier cuivré.

7. Câble selon la revendication 6, dans lequel les fils (24) de la couche de blindage intérieure sont constitués de fil d'acier galvanisé.

8. Câble selon la revendication 7, dans lequel les brins conducteurs (22) et les fils de blindage intérieurs (24) forment des espaces interstitiels (28) qui sont occupés par des fibres optiques gainées ou par des charges de fils d'acier galvanisé.

9. Câble selon la revendication 8, dans lequel les fils de la couche de blindage extérieure (32) sont des fils d'acier patentés, préfaçonnés et galvanisés.

10. Câble selon l'une quelconque des revendications précédentes, dans lequel l'âme centrale (12), les éléments conducteurs (22) et les fils de blindage intérieurs (24) sont enrobés d'une composition (26) de charge à base de caoutchouc nitrile.

11. Câble selon la revendication 1 ou 2, dans lequel l'âme centrale (12) est un fil plein, et en ce qu'il y a une à trois fibres optiques gainées réparties parmi les éléments conducteurs (22), qui sont des conducteurs isolés en fil d'acier cuivré, avec au total huit éléments conducteurs et fibres optiques.

12. Câble optique blindé selon la revendication 2, comprenant:

un élément d'âme central rond et sensiblement non déformable (12) ayant un diamètre extérieur d'environ 0,120 inch (0,305 cm), ledit élément d'âme (12) comprenant plusieurs fibres optiques (14) noyées dans un élastomère (16) et gainées d'une matière élastique dure (20);

huit brins conducteurs isolés sensiblement ronds et pleins (22) commis autour de et en contact avec ladite âme centrale (12), de sens vers la droite et suivant un pas d'environ 3,5 inches (8,89 cm), et d'un diamètre de 0,071 inch (0,180 cm), de manière que le diamètre extérieure de l'âme centrale et des brins

conducteurs soit d'environ 0,262 inch (0,665 cm);

seize fils de blindage intérieurs sensiblement ronds (24) constitués de fil d'acier galvanisé ayant un diamètre extérieur d'environ 0,058 inch (0,147 cm) commis autour de et en contact avec lesdits brins conducteurs (22), dans le même sens et suivant le même pas que lesdits brins conducteurs, lesdits éléments d'âme centraux (12), lesdits brins conducteurs (22) et lesdits fils de blindage intérieurs (24) formant un faisceau central (30) ayant un diamètre extérieur d'environ 0,368 inch (0,935 cm); et

vingt-quatre fils de blindage extérieurs sensiblement ronds (32) en fil d'acier galvanisé, commis autour de et en contact avec lesdits seize fils de blindage intérieurs (24), de sens vers la gauche avec un pas de 3,5 inches (8,89 cm), lesdits fils de blindage extérieurs ayant un diamètre d'environ 0,049 inch (0,124 cm) afin que le diamètre extérieur total du câble soit d'environ 0,469 inch (1,191 cm).

13. Câble selon la revendication 12, dans lequel la faisceau central (30) est garni d'un composé élastomérique (26) de charge.

14. Câble selon la revendication 13, dans lequel les interstices formés entre lesdits brins de blindage intérieurs et lesdits brins de blindage extérieurs sont garnis d'un inhibiteur de corrosion et lubrifiant (34).

15. Procédé pour fabriquer un câble blindé à fibres optiques (10) selon la revendication 1, lequel procédé consiste:

à commettre plusieurs éléments conducteurs isolés (22) en hélice autour d'un élément d'âme central (12), ledit commettage étant d'un sens donné et d'un pas donné;

à commettre une couche de plusieurs fils de blindage intérieurs (24), de même sens que lesdits éléments conducteurs (22) et au même pas, et appliqués en même temps que lesdits éléments conducteurs, en hélice autour de et en contact avec lesdits éléments conducteurs (22), au moins une fibre optique gainée (14) étant placée longitudinalement dans le faisceau central (30) formé par ledit élément d'âme central, lesdits éléments conducteurs et lesdits fils de blindage intérieurs; et

à fabriquer une couche de fils de blindage extérieurs (32) en contact avec ladite couche de fils de blindage intérieurs (24) et d'un sens opposé à celui de ladite couche de fils de blindage intérieurs et d'un pas tel que les couples excercés par lesdits fils de blindage intérieurs et extérieurs soient sensiblement équilibrés lorsque le câble est sous traction.

16. Procédé selon la revendication 15, qui consiste en outre à déposer des éléments interstitiels (28) dans l'espace interstitiel formé entre lesdits éléments conducteurs (22) et ladite couche intérieure de fils de blindage (24) en même temps que lesdits éléments conducteurs et ladite couche intérieure de fils de blindage sont formés.

