

UNDERWATER OPTICAL FIBRE CABLE

This invention relates to an optical fibre cable suitable for underwater use.

Such cables are subjected to tensile loading during laying and in use to radial compressive loading due to hydrostatic pressure which increases in relation to the depth at which the cable is laid and is present for the entire life of the cable. In order to protect the optical fibres of known optical fibre underwater cables from mechanical stresses caused by such loadings on the cable which would give rise to attenuation of the optical signal and may cause the fibres to break in view of their fragile nature, it has heretofore been the practice to provide underwater optical fibre cables with metallic reinforcement radially outwardly of the fibres against the tensile and the radial compressive loading to which it will be subjected. Examples of an optical fibre cable provided with metallic reinforcement disposed radially outwardly of the optical fibres thereof are disclosed in GB-A-2021252 and GB-A-2082790.

The presence of the metallic reinforcement in the known underwater optical fibre cables reduces the flexibility of the cables and increases the weight per unit length of the cable both of which factors make the laying of the cables more difficult. Further, as will be appreciated the deeper a cable is to be laid, the greater the amount of metallic reinforcement required radially outwardly of the optical fibres, thus increasing

the difficulty of the cable laying operation.

Also the greater the amount of metal per unit length in an optical fibre cable the greater the risk of metal corrosion giving rise to the production of hydrogen which acts on the optical fibres to increase the attenuation of the optical signals being transmitted thereby.

An object of the present invention is to provide an optical fibre cable suitable for use underwater having a construction which eliminates the need to provide the cable with metallic reinforcement radially outwardly of the optical fibres thereof against tensile and radial compressive loading dependent upon the depth at which the cable is to be laid underwater.

The present invention provides an optical fibre cable suitable for underwater use, comprising a central tensile resistant stranded member which is embedded in plastics material with the spaces between the strands of the central member being filled with a substantially incompressible fluid, the plastics material having a cylindrical outer surface provided with helically extending grooves which are closed by at least one layer disposed over said plastics material, at least some of the grooves containing at least one optical fibre element, the said grooves containing a substantially incompressible fluid to support the, or each, said layer against radially compressive, hydrostatic loadings encountered in use of the cable.

In this application the term 'fluid' as used in the expression 'substantially incompressible fluid' is intended to include viscous substances such as petroleum jelly and silicone grease, in addition to liquids. An example of a suitable liquid is silicone oil.

The optical fibre elements in the cable may comprise unjacketed optical fibres, optical fibres provided with tight jackets or optical fibres provided with loose jackets. When the optical fibres are provided

with loose jackets the space between the optical fibre and the loose jacket thereof in each optical fibre element is filled, or substantially filled, with a substantially incompressible fluid.

5           The layer disposed over the plastics material may comprise a water barrier, such as a metal sheath, in direct contact with said plastics material. Alternatively this layer may comprise a layer of plastics which may be interposed between the plastics material and a water  
10 barrier such as a metal sheath. When the helically extending grooves are closed by a layer of plastics, the plastics layer may have a cylindrical inner surface provided with radially inwardly extending ribs which extend into the grooves. In the case of the optical fibre  
15 elements comprising loose jacketed optical fibres, these ribs may fill the spaces between the grooves and the loose jackets.

          Preferably, the grooves have a radial depth and a circumferential width at said cylindrical outer surface  
20 not greater than 5 mm.

          The strands of the central member may comprise for example, steel wires, aromatic polyamide threads or carbon fibre threads, and preferably they include an electrically conductive element such as a copper wire.

25           In the preferred embodiments of the invention, the cable is devoid of any reinforcement against tensile and radial compressive loading radially outwardly of the optical fibre elements thereof.

          In order that the invention may be better understood, some embodiments thereof, which are given by way  
30 of example only, will now be described with reference to the accompanying drawings, in which:

          Figure 1 is a fragmentary perspective view of part  
of a submarine optical fibre telecommunications cable  
35 showing the structure thereof;

(12)

Figure 2 is a radial cross-section of another such cable; and

Figure 3 is a part radial cross-section of yet another such cable.

5 Referring now to Figure 1, there is shown a submarine optical fibre telecommunications cable suitable for use underwater at depths greater than 1000 metres. The cable has a cylindrical core 1 of plastics material and a central tensile resistant member 2 which is embed-  
10 ded therein. The member 2 is the radially innermost constituent of the cable, the axis of which is shown at 3 and is designed to provide the cable with sufficient tensile strength to withstand substantially all of the tensile loadings thereon during laying of the cable. The  
15 central member 2 comprises a compact antitorsionally stranded member having a plurality of strands 4 arranged in coaxial layers with the strands in adjacent layers extending helically in opposite senses.

The strands 4 are formed of a material having high  
20 tensile strength and for example are typically steel wires. Alternatively they may comprise aromatic polyamide threads or carbon fibre threads which have a tensile strength comparable to that of steel wires but have the advantage of reducing the metal content of the cable.

25 The plastics material in which the central member 2 is embedded comprises a layer 6 which has an inner surface which conforms to the outer surface presented by the central member. The plastics material of layer 6 may be a polyolefin, such as polyethylene, polyvinyl-  
30 chloride, nylon or other plastics material having a low coefficient of thermal expansion.

The spaces 5 between the strands 4 of the embedded central member 2, and any spaces between the member 2 and the layer 6, are filled with a substantially incompressible fluid, for example a petroleum jelly or a  
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silicone grease in order to support the member against radial compressive loading. As illustrated the strands are circular in cross-section, however when the strands are steel wires they may advantageously have cross-sections which reduce the size of the spaces therebetween, for example they may be trapezoidal in cross-section.

The outer surface of the layer 6, and thus of the core 1, is cylindrical and provided with a plurality of helically extending grooves 7. These grooves are closed by a layer disposed over and in contact with the layer 6 and which in the embodiment shown in Figure 1 comprises a water barrier formed by a water-tight metal sheath 9. At least some (and preferably each) of the grooves 7 contain at least one optical fibre element. Figure 1 shows the cable being provided with optical fibre elements in the form of unjacketed optical fibres 8, however they may comprise optical fibres provided with tight or loose jackets. The optical fibre elements 8 are loosely housed within the grooves 7, which have a radial depth and a circumferential width at the cylindrical outer surface of layer 6 not greater than 5 mm, and the remaining spaces in the grooves are filled with a substantially incompressible fluid, for example a petroleum jelly or a silicone grease. The fluid within the grooves supports the walls thereof and the layer 9 closing the grooves against radial compressive loadings.

A further plastics layer 10, for example of a polyolefin such as polyethylene is provided over the sheath 9 and other layers, for example of anti-ship-worm protection may be provided radially outwardly thereof. However, the cable is not provided with any metallic reinforcement radially outwardly of the optical fibre elements 8 against the tensile and the radial compressive loading to which the cable will be subjected. Such reinforcement which has heretofore been used despite

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the disadvantages associated therewith previously discussed has been found unnecessary in the embodiment because of the presence of a central member resistant to all tensile loading and of the virtual elimination of voids in the construction of the cable by filling the spaces 5 between the strands 4 of the central member 2 with substantially incompressible fluid and also by filling any spaces in the grooves 7 not occupied by the optical fibre elements 8 with substantially incompressible fluid. Thus with the exception of very small voids which are unavoidable in the manufacture of the cable there are virtually no spaces in the structure of the cable which are free from material and which will allow radial collapse of the cable. This feature of the cable enables it to withstand radial compressive loadings due to hydrostatic pressure at any depth underwater. This is in marked contrast with the prior cables where the metallic reinforcement provided radially outwardly of the optical fibres was considered essential and had to be increased with an increase in intended laying depth for the cable.

In connection with the above discussion regarding the metallic reinforcement of prior cables it is to be understood that the metal sheath 9 in the embodiment functions only to provide a water barrier and does not provide any significant mechanical resistance to either tensile or radially compressive loadings on the cable. Typically the thickness of the sheath 9 is of some tenths of a millimetre and remains substantially of that order no matter at what depth the cable is to be laid. The sheath 9 may be of aluminium and may be obtained by extrusion on to the layer 6. Alternatively it may be a metallic tape, again possibly of aluminium, which is wound longitudinally along the layer 6 with its edges either abutting or overlapping and subsequently soldered, welded or sealed with a mastic material.

If the optical fibre elements 8 do not comprise either unjacketed or tight jacketed optical fibres but instead comprise optical fibres provided with loose jackets, the remaining space between the optical fibre and the loose jacket thereof, which may be a plastics or metal tube, in each optical fibre element contains a substantially incompressible fluid, for example a petroleum jelly or a silicone grease. The fluid within the jacket supports the walls thereof against radial compressive loading. Preferably the remaining space is completely filled with this fluid. If this space is not completely filled with the fluid the jacket itself has to be able to withstand the compressive loading to a greater extent than if the space were completely filled. This may be achieved by increasing the wall thickness of the tube forming the jacket.

Referring now to Figure 2, there is illustrated submarine optical fibre cable which has a construction the same as that illustrated in Figure 1, except that there is interposed between the metal sheath 9 and the core 1 a layer 11 of plastics material, which may, but need not, be the same material as that forming the layer 6 of the core. Thus it is the plastics layer 11 which closes the grooves 7 in the embodiment shown in Figure 2, rather than the metal sheath 9. As illustrated, the inner surface of the layer 11 which is in direct contact with the outer surface of the core is cylindrical with a circular cross-section. However, this inner cylindrical surface may be provided with radially inwardly extending ribs which extend into the grooves 7 to reduce the spaces left in the grooves not occupied by the optical fibre elements which have to be filled with the substantially incompressible fluid.

The optical fibre elements in the cable constructions discussed in connection with Figure 2 like those in the cable construction of Figure 1 may comprise unjacketed optical fibres, tight-jacketed optical fibres or loose jacketed optical fibres.

When the optical fibre elements are loose jacketed, the ribs of the plastics layer interposed between the core and metal sheath may be arranged to fill the space between the loose jackets of the optical fibre elements and the grooves, as shown in Figure 3. The cable illustrated in Figure 3 has the same general construction as the cable illustrated in Figure 2. However, the helical grooves provided at the outer surface of the core 1, and referenced 12 in Figure 3, each contain a single optical fibre element comprising an optical fibre 14 provided with a loose jacket in the form of a plastics or metal tube 13. The helical grooves 12 have a base which is semi-circular in section and of the same radius as the outer surface of the tubes 13 so that the tubes contact the bases of the grooves over the entire width of the grooves. A plastics layer 15 disposed over the core 1 in contact with the outer surface thereof is provided with radially inwardly extending ribs 16 which extend into the grooves to fill the spaces therein left free by the tubes 13. Thus each rib has a radially outwardly opening semi-circular recess having the same radius as that of the outer surface of the tube 13.

When the tube 13 is formed of a plastics material, for example a polyolefin such as polyethylene the layer 15 may be of the same material. However, this is not essential and for example the plastics tube 13 may be nylon and the layer 15 a polyolefin.

In the cable illustrated in Figure 3, an optical fibre element occupies all of the space in each groove 12 subsequent to the closure thereof by the layer 15, and accordingly the need to provide any substantially incompressible fluid to fill spaces in the grooves left unoccupied by the optical fibre elements is eliminated. However, the space remaining within each tube 13 which loosely houses an optical fibre should contain, and

preferably be completely filled with, substantially incompressible fluid for supporting the walls of the tube against radial compressive loading as discussed above in connection with the use of loose jacketed optical fibres in the cable construction illustrated in Figure 1.

The layer 15 of plastics material is covered by a water-tight metal sheath 17 corresponding with the sheath 9 in Figure 2, and this sheath 17 is covered with a further layer 18 of plastics material.

In any of the embodiments the strands of the central member may include an electrically conductive element, for example a copper wire, which is used together with the metal sheath 9 to provide electric power to optoelectronic repeaters for the optical signals being transmitted. One or more of such conductive elements may be embedded in the other strands 4 or wound around those strands. In prior arrangements, the metal sheath has been used to supply power to such repeaters with the water surrounding the cable functioning as the return conductor and a plastics layer over the metal sheath acting as a dielectric. In the proposed arrangements for the embodiments of the invention, it is the plastics material of the core 1, that is the plastics layer 6, which acts as a dielectric and accordingly the plastics layer 10 or 18 covering the sheath is not subjected to electrical stresses which together with the action thereon of the surrounding water leads to the formation of so-called 'water-trees' in this plastics layer and to corrosion of the metal sheath, in the prior arrangements.

From the foregoing it will be appreciated that embodiments of the invention can be made more flexible and easier to handle than prior underwater optical fibre cables which have utilised metallic reinforcement radially outwardly of the optical fibres and that the

elimination of such reinforcement reduces the risk of hydrogen being produced and acting on the optical fibres to increase the attenuation of the optical signals being transmitted thereby.



CLAIMS:

1. An optical fibre cable suitable for underwater use, comprising a central tensile resistant stranded member which is embedded in plastics material with the spaces between the strands of the central member being filled with a  
5 substantially incompressible fluid, the plastics material having a cylindrical outer surface provided with helically extending grooves which are closed by at least one layer disposed over said plastics material, at least some of the grooves containing at least one optical fibre element, the  
10 said grooves containing a substantially incompressible fluid to support the, or each, said layer against radially compressive, hydrostatic loadings encountered in use of the cable.
2. A cable as claimed in claim 1, wherein said optical fibre elements comprise unjacketed optical fibres.
- 15 3. A cable as claimed in claim 1, wherein said optical fibre elements comprise optical fibres provided with tight jackets.
4. A cable as claimed in claim 1, wherein said optical  
20 fibre elements comprise optical fibres provided with loose jackets.
5. A cable as claimed in claim 4, wherein the space between the optical fibre and the loose jacket thereof in each optical fibre element is filled, or substantially filled,  
25 with a substantially incompressible fluid.
6. A cable as claimed in any one of the preceding claims, wherein one said layer disposed over the plastics material comprises a water barrier in direct contact with said plas-  
30 tics material.
7. A cable as claimed in claim 6, wherein said water barrier comprises a metal sheath.
8. A cable as claimed in any one of claims 1 to 5,  
35 wherein said layer or one of said layers comprises a layer of plastics.



9. A cable as claimed in claim 8, wherein said plastics layer has a cylindrical inner surface provided with radially inwardly extending ribs which extend into said grooves.
- 5 10. A cable as claimed in claim 9, when claim 8 is appended to claim 4 or 5, wherein said ribs fill the spaces between the loose jackets of the optical fibre elements and said grooves.
- 10 11. A cable as claimed in claim 8, 9 or 10, wherein said plastics layer is interposed between said plastics material and a water barrier *layer*.
12. A cable as claimed in claim 11, wherein said water barrier comprises a metal sheath.
- 15 13. A cable as claimed in any one of the preceding claims, wherein the grooves have a radial depth and a circumferential width at said cylindrical outer surface not greater than 5 mm.
- 20 14. A cable as claimed in any one of the preceding claims, wherein the strands of said central member comprise steel wires.
15. A cable as claimed in any one of claims 1 to <sup>13</sup>/~~14~~, wherein the strands of said central member comprise aromatic polyamide threads.
- 25 16. A cable as claimed in any one of claims 1 to <sup>13</sup>/~~14~~, wherein the strands of said central member comprise carbon fibre threads.
17. A cable as claimed in any one of the preceding claims, wherein the strands of said central member include at least one electrically conductive element.
- 30 18. A cable as claimed in claim 17, wherein the or each electrically conductive element comprises a copper wire.
- 35 19. A cable as claimed in any one of the preceding claims and devoid of any reinforcement against tensile and radial compressive loading radially outwardly of the optical fibre elements thereof.



20. A cable as claimed in any one of the preceding claims, wherein said central member is adapted to withstand substantially all of the tensile loadings on the cable during laying of the cable.

- 5 21. An optical fibre cable suitable for underwater use, substantially as herein described with reference to Figure 1, 2 or 3 of the accompanying drawings.
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