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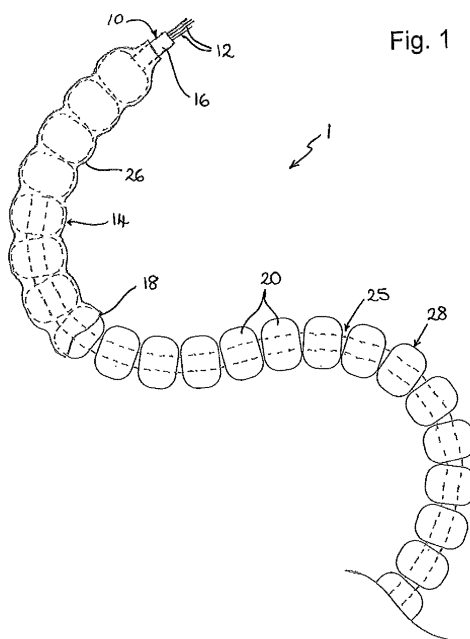
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DE 003110008 A1 **US 5197767 A**
US 5143123 A **US 4696542 A**
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(54) Title of the Invention: **Armoured cable**
Abstract Title: **Armoured underwater fibre optic cable**

(57) An armoured sleeve 1 for protecting optical fibres 12 underwater, and a method of manufacture and use. The sleeve has a protective outer layer 18 surrounding a polymeric inner layer (17, fig 2). The inner layer defines an elongate conduit 16 for holding the optical fibres and the outer layer has a series of discrete non-metallic beads 20 in proximity to one another, where each bead has an aperture (22, fig 2) for the conduit. The beads may be glass, moveable relative to one another, and water may flow between them. The beads may have separate identical halves (30, 32, fig 3a) with flat or clipping tongue and groove abutting surfaces (34, 34', fig 3a). There may be an elastomeric outer sheath 26 conforming to the undulating external shape 28 of the beads, and may hold the bead segments together. In another aspect of the invention, the method relates to adjacent non-connected beads.



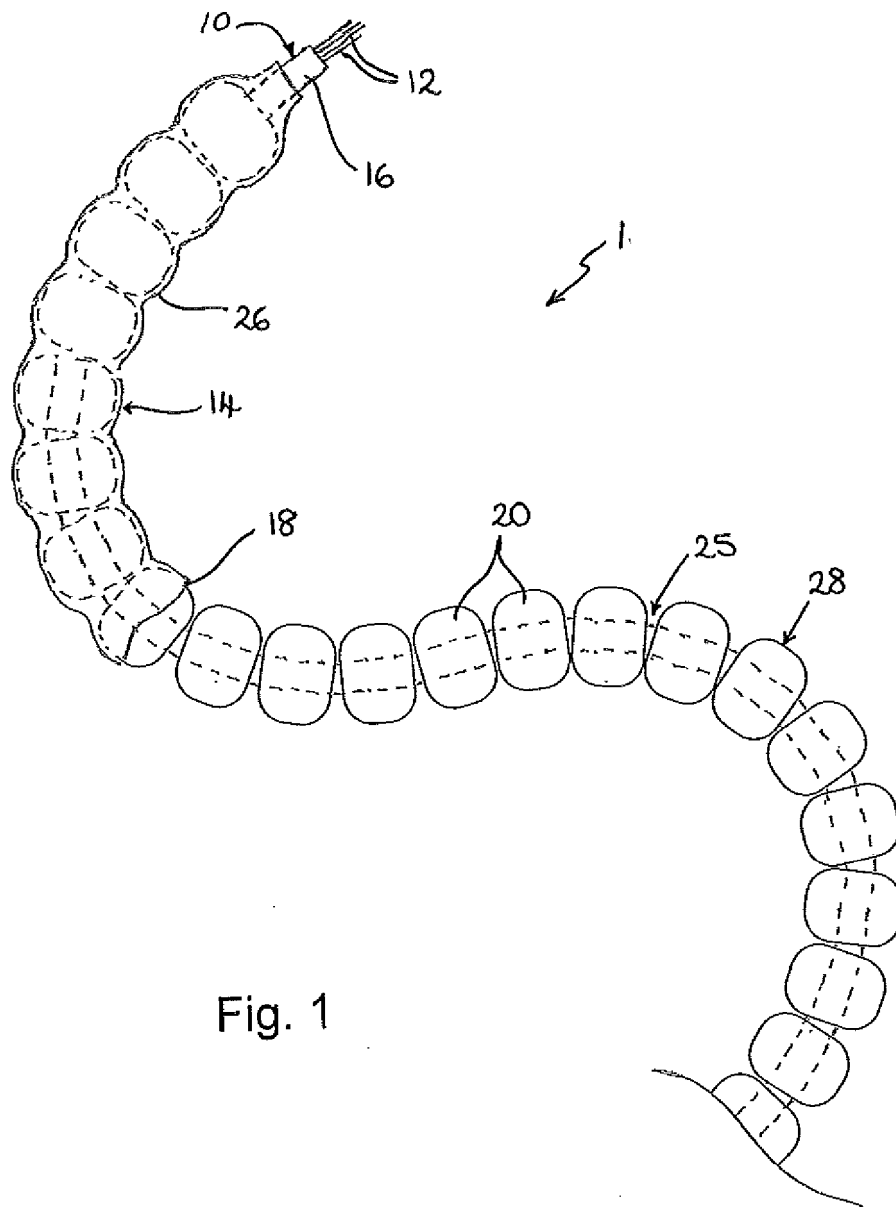
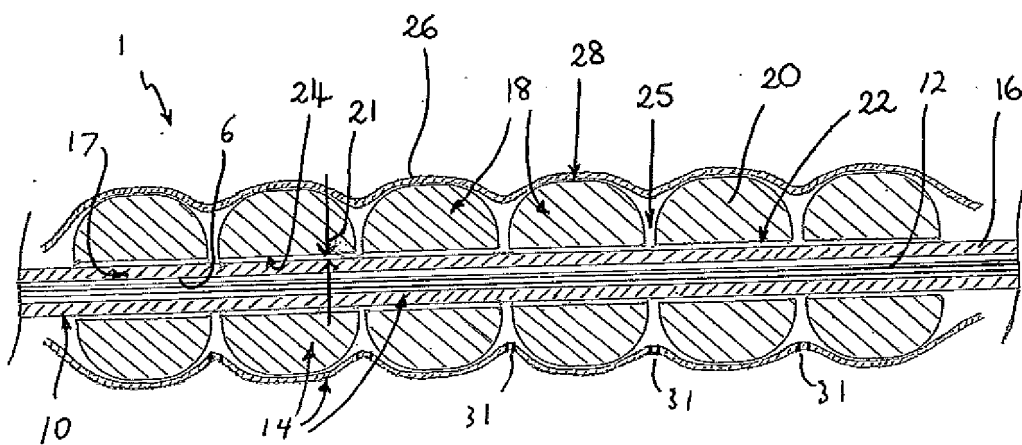


Fig. 1



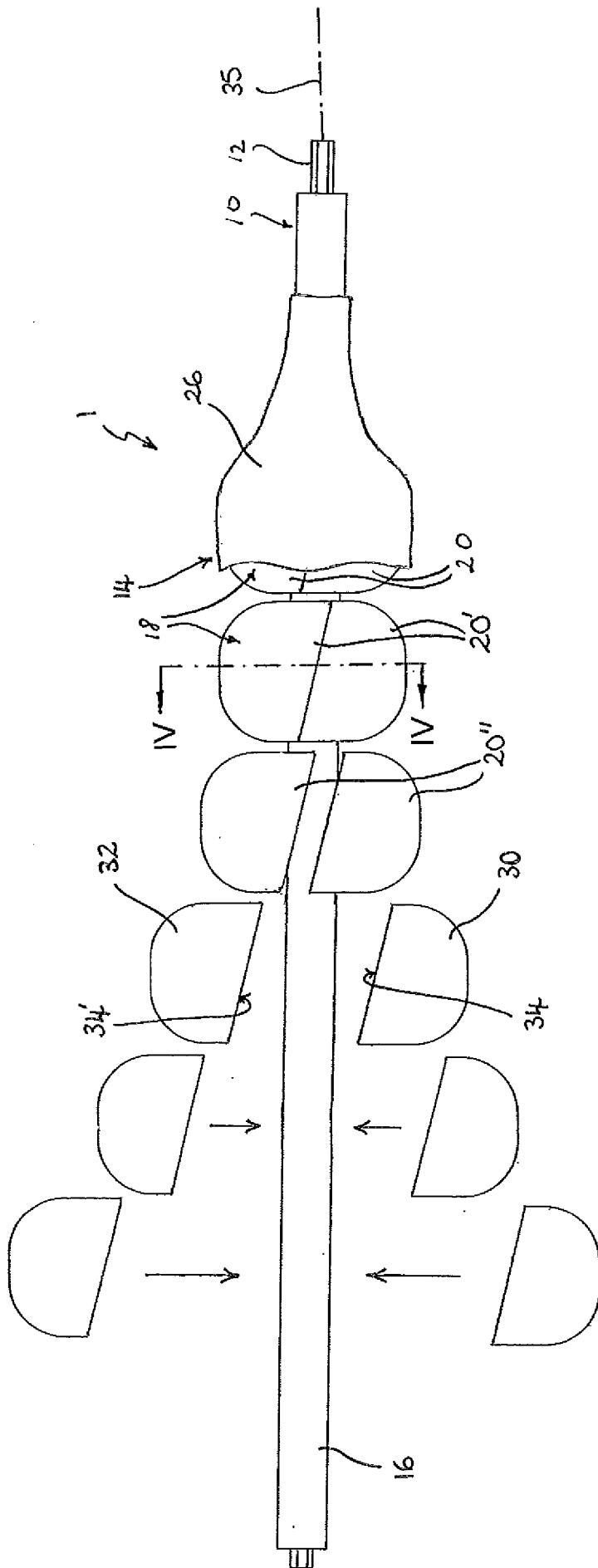


Fig. 3a

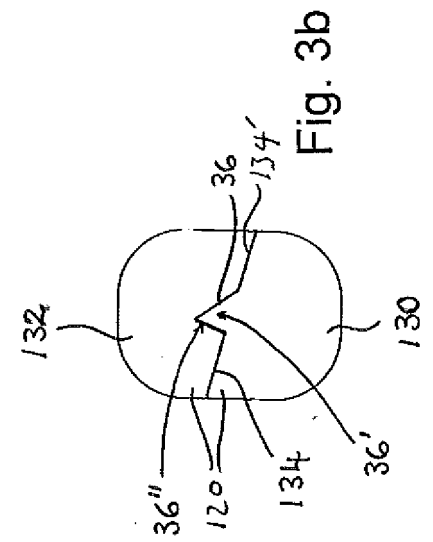


Fig. 3b

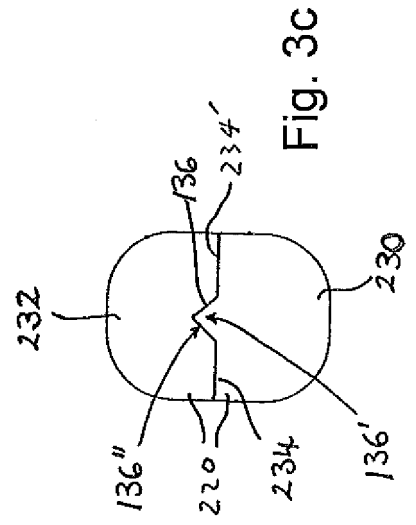


Fig. 3c

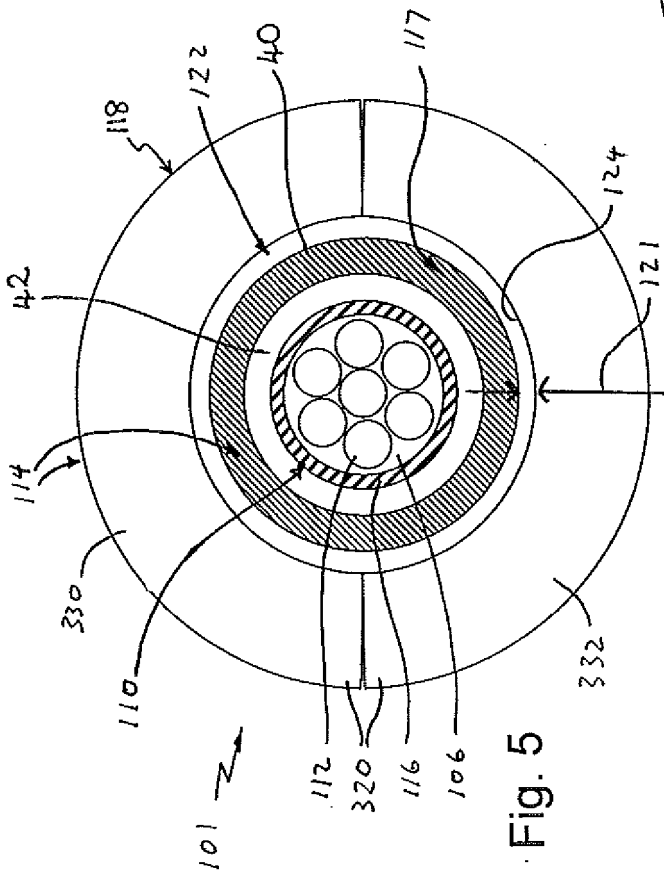


Fig. 5

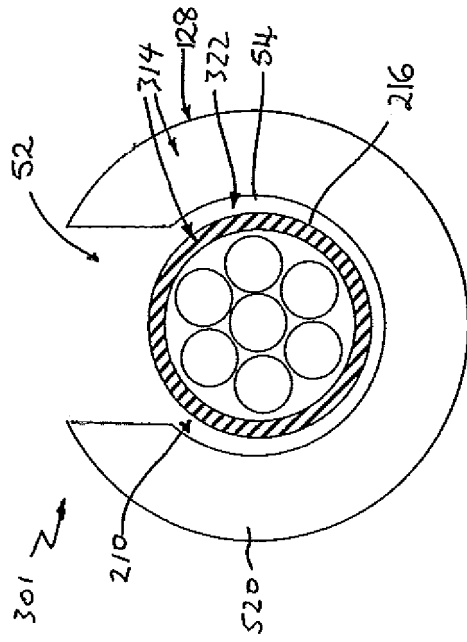


Fig. 7

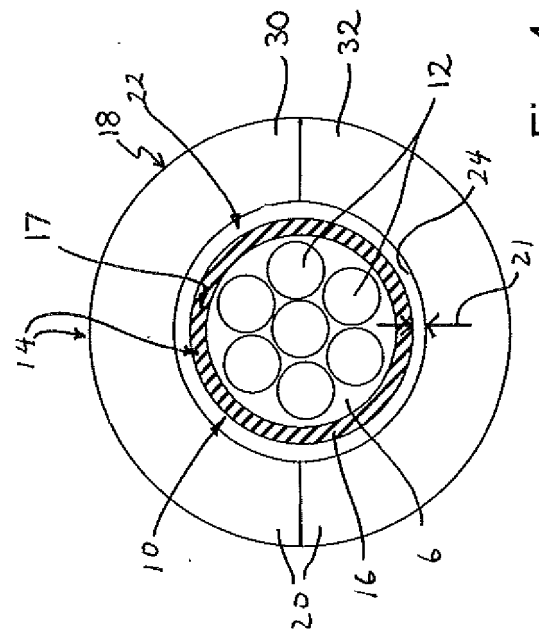


Fig. 4

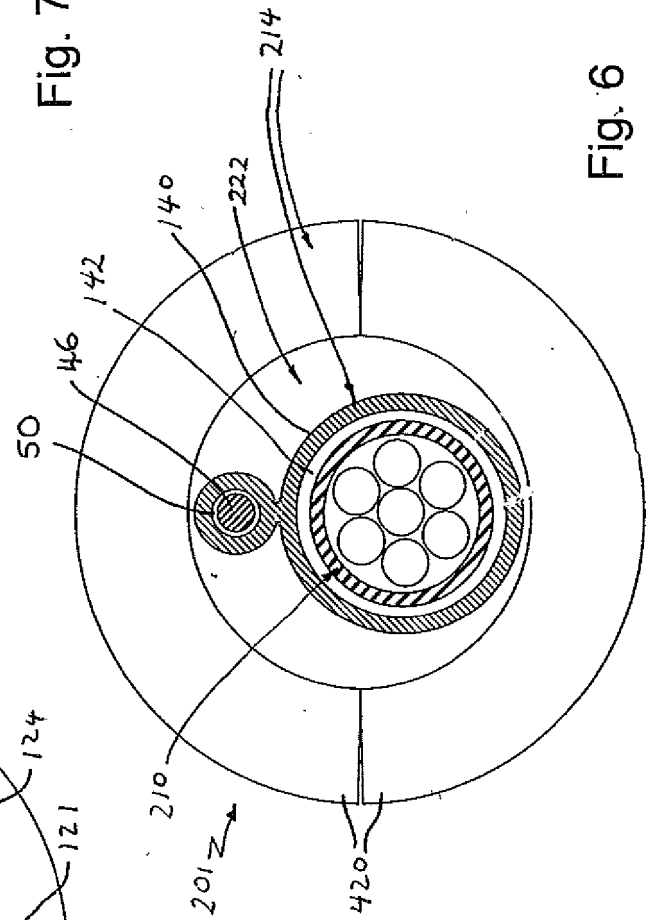


Fig. 6

Armoured Cable

BACKGROUND

5 a. Field of the Invention

This invention relates to armoured cables and in particular to an armoured sleeve for surrounding and providing outdoor underwater protection to a length of optical fibre, an armoured optical fibre cable and a method of manufacturing an armoured
10 sleeve.

b. Related Art

Standard optical fibre cables can be at risk of damage in outdoor underwater
15 installations due, in part, to contact with sharp objects such as stones, and also from bending stresses and crush forces. This is particularly the case if the optical fibre cable is laid underwater to cross a river or lake, for example. In this environment it is not only necessary to protect the cable from the action of the water, but also from other potential hazards, such as the cable being caught by a
20 boat's anchor. Therefore, underwater optical fibre cables are often buried beneath the lake bed or river bed. Burying a cable underwater adds cost and increases the time needed to run the cable.

In these situations, therefore, it is necessary and desirable to provide increased
25 protection, generally in the form of increased crush resistance, around the optical fibre cable. A secondary consideration in underwater applications is that the cable must be sufficiently heavy to remain on the bottom of the river or lake, otherwise the cable must be buried. The usual way of achieving this is to add a steel wire of sufficient weight to the cable or by providing metal weights to anchor the cable at
30 points along its length.

A number of types of armoured cable are well known in the industry. These

armoured cables typically comprise a plurality of layers each providing specific protection to the central optical fibre. The majority of armoured cables comprise a plurality of steel wires that wrap around and extend along the length of the cable surrounding the optical fibre core providing both crush resistance and tensile strength. Other types of armoured cable comprise fibre reinforced plastic layers to provide the crush resistance. These non-metallic armoured cables may comprise glass fibres or Kevlar (Reg. TM).

Although all of the known prior art armoured cables are able to provide sufficient protection to the optical fibre core, they are complex and expensive to manufacture. Furthermore, their construction is such that they are substantially more rigid than non-armoured cables, which makes transportation and handling of the cables very difficult. Steel is also prone to corrosion in underwater environments, particularly in salt water, with the consequence that the steel may need to have a corrosion resistant composition or incorporate a protective surface coating.

It is, therefore, an object of the present invention to provide a cheaper and more flexible armoured optical fibre cable for underwater installation, for example, across a lake, stream or river or in the sea, as compared to prior art armoured optical fibre cables.

SUMMARY OF THE INVENTION

According to a first aspect of the invention there is provided an armoured sleeve for surrounding and providing underwater protection to a length of optical fibre, the armoured sleeve comprising:

- a protective polymeric inner layer that provides an elongate conduit for holding an optical fibre; and
- around said inner layer a protective outer structure comprising a plurality of discrete non-metallic beads, each bead having a passage therethrough and the conduit being retained within said passages,

wherein the beads are positioned in proximity with one another along the length of the conduit to provide crush protection along the length of the conduit, the beads having sufficient density that the armoured sleeve sinks in water.

- 5 The polymeric tubing will, in general, have a density less than that of water so that the conduit will naturally not sink without negative buoyancy provided by the plurality of beads. In some embodiments, the polymeric tubing will initially have a hollow interior that contains air. This may be advantageous, for example allowing the fibre to be installed inside the conduit by blowing air down the conduit when
10 playing out from a spool a length of fibre, which may be simultaneously pushed along the length of conduit.

In a preferred embodiment the beads are positioned adjacent one another along the length of the conduit to provide crush protection continuously along the length
15 of the conduit. Typically the beads will be moveable along the length of the conduit and with respect to one another. This is achieved by loosely spacing the beads along the length of the conduit such that there exist gaps between at least some of the adjacent beads.

- 20 The advantage of using non-metallic materials is that they are not affected by lightning and in general have a lower mass than metals such as steel so that the armoured sleeve remains easy to manipulate. The beads have sufficient density that the armoured cable sinks in water once fully constructed. This allows the armoured cable to be quickly and easily deployed in underwater areas, such as
25 crossing a river or lake, without requiring the cable to be buried.

In preferred embodiments the beads are made of glass. More preferably the beads are made of recycled glass. It is advantageous to form the beads from recycled glass as this is more energy efficient and environmentally friendly than forming
30 them from new glass. Additionally, the use of recycled glass is more cost effective resulting in a lower cost armoured sleeve.

The protective outer structure preferably further comprises an outer sheath extending continuously along the length of the conduit, said plurality of beads being held between the outer sheath and the conduit. The outer sheath provides additional protection to the optical fibre cable and can be used to weatherproof the cable.

Preferably the outer sheath is elastomeric and is stretched over the beads so that the outer sheath at least partially conforms to an undulating external shape of said beads.

According to a second aspect of the invention, there is provided an armoured optical fibre cable comprising an armoured sleeve according to the first aspect of the invention, and at least one optical fibre extending through the elongate conduit.

Also according to a third aspect of the invention, there is provided a method of constructing an armoured sleeve for protecting a length of optical fibre, the armoured sleeve comprising a protective polymeric inner layer that provides an elongate conduit having at least one bore for receiving a length of optical fibre and having a density insufficient such that the conduit will sink in water, and a plurality of discrete beads, each of said beads having a passage therethrough for receiving a part of the conduit, the method comprising the steps of:

- i) securing a first one of said beads around the conduit;
- ii) securing a second one of said beads around the conduit directly adjacent to the first bead such that the first and second beads are non-interconnected; and
- iii) repeating steps i) and ii) along a length of the conduit such that beads are positioned in proximity with one another along the length of the conduit to provide crush protection along said length of conduit and to provide sufficient weight around the conduit such that that the armoured sleeve will sink in water.

The beads are discrete beads, most preferably glass beads, spaced along the length of the conduit.

In preferred embodiments the method further comprises covering the beads with an outer sheath that extends continuously along the length of the conduit. The outer sheath is advantageously made from an elastomeric material, and the method preferably comprises the step of applying the outer sheath around the
5 beads along the length of the conduit so that the sheath at least partially conforms to an external shape of the beads.

According to a fourth aspect of the invention, there is provided a method of constructing an armoured optical fibre cable comprising an armoured sleeve and
10 at least one optical fibre protected within said sleeve, the method comprising the steps of constructing the armoured sleeve according to the third aspect of invention, and further comprising the step of inserting said optical fibre through said bore of the conduit, the beads being secured around the conduit either before or after the optical fibre cable is inserted through said bore of the conduit.

15

The body of water may be a lake, a stream or river, or the sea and will, in general, have a floor, for example of mud, sand, gravel or rocks, and the armoured optical fibre cable will, after being placed in the body of water then sink in the water under its own weight, thereby laying the armoured optical fibre on the floor of the body of
20 water.

The method may also comprise the steps of forming a trench in the floor of the body of water into which trench said cable is laid, and then back-filling the trench to bury the armoured optical fibre in the trench, the plurality of beads providing
25 crush resistance within the back-filled trench.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be further described, by way of example only, and with
30 reference to the accompanying drawings, in which:

Figure 1 shows a portion of an optical fibre within an armoured sleeve

according to a first embodiment of the present invention;

Figure 2 is a longitudinal cross-sectional view of a part of the armoured sleeve of Figure 1;

5

Figure 3a is a diagram illustrating a method of construction of the armoured sleeve of Figure 1, including coupling a plurality of beads around an inner conduit;

10

Figure 3b illustrates another embodiment of one of the beads of Figure 3a;

Figure 3c illustrates a further embodiment of one the beads of Figure 3a;

15

Figure 4 is a tangential cross-sectional view of an optical fibre within an armoured sleeve according to the first embodiment of the present invention, with an outer sheath removed, taken along line IV-IV of Figure 3a;

20

Figure 5 is a tangential cross-sectional view of an optical fibre within an armoured sleeve according to a second embodiment of the present invention;

25

Figure 6 is a tangential cross-sectional view of an optical fibre within an armoured sleeve according to a third embodiment of the present invention; and

Figure 7 is a tangential cross-sectional view of an optical fibre within an armoured sleeve according to a fourth embodiment of the present invention.

DETAILED DESCRIPTION

30

Figures 1 and 2 show a length of an armoured optical fibre cable 1 according to a first embodiment of the present invention. The armoured optical fibre cable 1

comprises an armoured sleeve 14 that surrounds one or more optical fibres 12. The armoured sleeve provides protection to the optical fibres, particularly in the form of improved crush resistance.

- 5 The optical fibres are part of an optical fibre cable 10 that also comprises a continuous, elongate polymeric sheath 16 that has along its length a bore 6 inside of which the optical fibres 12 are tightly held. As the optical fibres are carried by the sheath, the sheath forms a conduit 16 for the optical fibres, and will therefore be referred to as such in the following description.

10

The optical fibres 12 may be multimode or single mode optical fibres, but in this example are conventional single mode optical fibres. Although not illustrated, each of the optical fibres 12 is of a conventional form that will be familiar to those skilled in the art, having a core (8 μm diameter), which is inside cladding (125 μm diameter). The cladding is surrounded by an outer buffer layer (250 μm diameter) and an outer jacket (400 μm diameter).

Each of the optical fibres 12 is therefore individually coated and insulated as is known in the art. The conduit 16 of the optical fibre cable 10 forms an inner layer 17 of the armoured sleeve 14. The conduit 16 is flexible and is made of a suitable plastics or polymeric material. The conduit 16 and bundle of fibres 12 together form the optical fibre cable 10.

25 The armoured sleeve 14 further comprises a protective outer structure 18 which provides crush protection to the conduit 16. The protective structure 18 includes a plurality of discrete and separate beads 20. Each of the beads 20 is toroidal in shape and includes a central passage or hole 22 sized to receive the conduit 16. This is most clearly illustrated in Figure 2. The diameter of the hole 22 is, preferably, slightly larger than the outer diameter of the conduit 16 so that there is a clearance or gap 21 between the conduit 16 and an inner surface 24 of the bead 20 defined by the hole 22. This permits axial movement of each of the beads 20 along the conduit 16.

The beads 20 may be of any suitable shape, for example toroidal or substantially cylindrical, and preferably each bead 20 fully surrounds the conduit 16; however, in other embodiments the beads may only partially surround the conduit 16 as described further below.

The beads 20 are made from a substantially rigid material having a high crush resistance or compressive strength and with a density greater than that of water. In this embodiment the beads 20 are made of glass, and in particular recycled glass. In other embodiments the beads 20 may be made from another suitable non-metallic material such as a ceramic material or a high density plastics material. The optical fibre cable 10 has a density less than that of water and the beads have a sufficient mass and density such that the armoured sleeve 14 and the armoured optical fibre cable 1 will sink in water.

The beads 20 are secured or coupled to the conduit 16 so that the beads 20 are adjacent to each other but are not interconnected. The beads 20 are secured along the length of the conduit 16 such that movement of each bead 20 is permitted in a longitudinal or axial direction along the conduit 16. In particular, the beads 20 are arranged along the conduit so that it is possible to form a clearance or gap 25 between each bead 20. This loose spacing of the beads 20, such that the beads 20 are not pressed tightly against one another, means that each bead, on average, occupies a space comprising a length of conduit 16 greater than the width of a bead 20 in a longitudinal or axial direction.

This permitted longitudinal or axial movement, together with the radial movement permitted by the clearance 21 between the conduit 16 and the inner surface 24 of each bead 20, allows the beads 20 to move with respect to each other and the conduit 16 as the armoured optical fibre cable 1 is bent. The beads 20 will, therefore, tend to become more spaced apart in regions of the armoured optical fibre cable 1 having a smaller radius of curvature and may move to sit closer together along straighter regions of the armoured optical fibre cable 1.

To further protect the glass beads 20 and to retain the beads in position around the conduit 16, the armoured optical fibre cable 1 also includes an outer sheath 26. The outer sheath 26 is preferably made from an elastomeric material and may
5 be made from vulcanised natural rubber. The outer sheath 26 provides a further layer of crush resistance and an outer weather proof barrier layer.

Although the outer sheath 26 may have a density less than that of water, the outer sheath is sufficiently thin and the beads 20 have a sufficient mass and density
10 such that together with the outer sheath 26, the weight of the outer sheath, beads and conduit 16 in water is sufficient to make the armoured sleeve 14 and the assembled armoured optical fibre cable 1 sink in water.

The outer sheath 26 is relatively thin compared to the thickness of the glass beads
15 20 and, as shown most clearly in Figure 2, the outer sheath 26 substantially conforms to the undulating shape of an outer surface 28 of the beads 20. The outer sheath 26 is flexible such that movement of the beads 20 is still permitted and the flexibility of the armoured optical fibre cable 1 is maintained.

20 If the beads are of one piece and toroidal in shape, the beads would have to be threaded onto the conduit from one end of the conduit, which would be inconvenient.

Figure 3a illustrates a method of constructing the armoured optical fibre cable 1
25 described above, and Figure 4 shows a cross-section through Figure 3a.

So that the beads 20 do not have to be threaded onto the end of the conduit 16, each of the beads 20 is formed in two separate abutting segments 30, 32 which when brought together in abutting contact form a single bead divided by a cut. The
30 two separate segments 30, 32, when joined, for example by gluing or bonding, extend on opposite sides of the conduit 16 and fully surround the conduit. The separate segments 30, 32 have the same shape and are therefore

interchangeable with each other such that any two segments 30, 32 may be joined together to form the bead 20. This allows a bead 20 to be secured to the conduit 16 directly at any point along its length. In this example, the cut or interface between two bead segments extends through the bead 20 and intersects the passage 22 to form two identical and therefore interchangeable segments 30, 32. In this way, the two segments 30, 32 have therebetween two pairs of planar mating or abutting surfaces 34, 34' which are parallel with the conduit axis 35 and which abut against each other when the segments 30, 32 are installed on opposite sides around the conduit 16. In other embodiments the two segments may not be identical, however it is preferred if the segments are at least interchangeable to facilitate assembly of the armoured sleeve.

To form the armoured optical fibre cable 1 the segments 30, 32 are brought together around the conduit 16 so that the mating surfaces 34, 34' abut and the segments 30, 32 form a complete bead 20. In particular, a first one of the segments 30 is positioned against the elongate conduit 16 with each one of its pair of mating surfaces 34 being on an opposite side of the conduit 16 from the other. Then a second one of the segments 32 is similarly positioned against the elongate conduit 16 with each one of its pair of mating surfaces 34' being on an opposite side of the conduit 16 from the other. Each one of the mating surfaces 34, 34' in each segment 30, 32 can then be brought into abutting contact with an opposed mating surface of the other segment.

In a simplest embodiment the cut or interface through the bead 20 is parallel to a longitudinal axis of the passage 22 so that the mating surfaces 34 extend substantially parallel to a longitudinal axis 35 of the conduit 16 when the segments 30, 32 are assembled into a bead 20. In preferred embodiments, however, the cut is made so that the mating surfaces 34 are not parallel to the longitudinal axis 35. In this way, the mating surfaces 34 of neighbouring beads 20 do not form a continuous line along the length of the armoured optical fibre cable 1. As shown in Figure 3a, in preferred embodiments the mating surfaces 34 extend at an angle of between 5° and 20° to the longitudinal axis 35.

Figure 3b shows a second embodiment of the beads 120, in which features corresponding with those of the first embodiment of the beads 20 are indicated using reference numerals incremented by 100 and Figure 3c shows a third embodiment of the beads 220 in which features corresponding with those of the first embodiment of the beads 20 are indicated using reference numerals incremented by 200. As illustrated in Figures 3b and 3c, each one of a pair of interchangeable segments 130, 132, 230, 232 is used to form a single bead 120, 220 that includes a complementary interengaging feature 36, 136 on substantially planar mating surfaces 134, 134', 234, 234' that are set at an angle (preferably between 5° and 20°) to the conduit axis 35. In these examples the interengaging features 36, 136 are tongue and groove formations, each segment having on one side of the conduit axis 35 a tongue 36', 136' and on the other side of the axis a groove 36'', 136'' for receiving the tongue so that the segments have identical shapes and are interchangeable.

As the segments 130, 132, 230, 232 are brought together around the conduit 16, corresponding interengaging features 36, 136 engage so that the two segments 130, 132, 230, 232 align correctly. The interengaging features 36, 136 also prevent the two segments 130, 132, 230, 232 moving with respect to one another along the length of the conduit 16 once the segments 130, 132, 230, 232 are engaged.

In a variation of the second and third embodiments of the beads, not illustrated in the drawings, the segments of the beads may be formed with an interlocking feature that secures and holds the two segments together when in correct alignment with each other when the segments are located around and on opposite sides of the conduit 16. For example, a push fit locking feature may be incorporated into the mating surfaces of segments made from a high density plastics material.

The principle of construction of an armoured sleeve 14 for surrounding and

protecting a length of optical fibre is the same when using any of the embodiments of bead 20, 120, 220 described above, and so is described below just in relation to the first embodiment of bead shown in Figure 3a.

- 5 To construct a length of armoured sleeve 14, a plurality of beads 20 is secured or coupled to the conduit 16 along its length. In particular, a first bead 20' is coupled to the conduit 16 and a second, neighbouring bead 20'' is then coupled to the conduit 16 directly adjacent to the first bead 20'. These beads are not interconnected and remain discrete and separate along the length of the
10 conduit 16.

Each of the beads 20 is coupled to the conduit 16 so that it is free to move along the length of the conduit 16 until stopped by contact with another bead. In particular, a number of beads 20 are secured along a defined length of the conduit
15 16 so that each bead is loosely spaced with respect to the immediately adjacent bead, whereby water can flow freely between said beads and into the gaps 21 in the passages 22 when the armoured sleeve is immersed in water. The outer sheath 26 may include perforations 31 to allow water to flow and replace air inside the armoured sleeve. Therefore, there is play between the beads 20 and adjacent
20 beads are not restricted to being continuously in touching contact, and can slide when necessary, for example to accommodate bending of the armoured optical fibre cable 1.

To retain the beads 20 around the conduit 16 and to further protect the conduit 16,
25 the outer sheath 26 is then formed around the beads 20, to cover and encapsulate the beads 20. The outer sheath 26 is preferably made of a thermoplastic material and extends continuously along the length of the conduit 16 so that the beads 20 are held between the conduit 16 and the outer sheath 26. The outer sheath 26 is stretched over the beads to form the protective structure 18 and, as shown in
30 Figures 1 and 3a, at least partially conforms to a part of the external surfaces of the beads 20. The outer sheath 26 thereby holds the abutting segments 30, 32 together. To aid this, the outer sheath 26 may also be elastomeric and exert a

compressive force on the beads. The outer sheath 26 may be used as an alternative to, or in addition to, other means of joining or holding the bead segments together, such as glue or ultrasonic bonding.

- 5 The armoured sleeve 14 of the present invention may be applied directly to the optical fibre cable 10, as described above, or may be applied to a duct or microduct used to convey one or more optical fibre cables 10.

10 In the embodiments described above, the optical fibre cable 10 is manufactured with the optical fibres 12 embedded within the polymeric material forming the sheath or conduit 16. The beads 20, 120, 220 are then applied around the cable prior to installation outdoor underwater. The invention is, however, also applicable to the case where the armoured sleeve is formed with a hollow conduit through
15 fibres, may be inserted, either before or after outdoor underwater installation of the armoured sleeve. Such later insertion of optical fibres may be achieved using known methods, such as by pulling a pre-installed wire running the length of the conduit, or by blowing and pushing the optical fibre down the length of conduit.

- 20 An example of this is shown in Figure 5, which is a schematic cross-sectional view of an armoured optical fibre cable 101 according to a second embodiment of the present invention. As in the first embodiment, the armoured optical fibre cable 101 comprises an armoured sleeve 114 that surrounds at least one length of optical fibre, in this example seven optical fibres 112.

25 The optical fibres are part of an optical fibre cable 110 that also comprises a continuous, elongate retaining sheath 116 that has along its length a bore 106 inside of which the optical fibres 112 are held. As before, the optical fibres 112 may be multimode or single mode optical fibres, but will most usually be single
30 mode optical fibres individually coated and insulated as is known in the art.

The sheath 116 is flexible and is made of a suitable plastics or polymeric material.

The sheath 116 and bundle of fibres 112 together form the optical fibre cable 110.

5 The armoured sleeve 114 further comprises a protective outer structure 118 which provides crush protection to the optical fibre cable 110. Unlike the first embodiment, the protective structure 118 is not provided directly around the optical fibre cable 110. The second embodiment differs from the first embodiment 1 in that it is not the optical fibre sheath 116 that forms an inner layer 117 of the armoured sleeve 114, but rather a hollow elongate polymeric tube 40, often referred to as a "microduct". In this embodiment, it is therefore the hollow tube 40
10 that provides the conduit for the optical fibres 112 and surrounding sheath 116.

The protective structure 118 includes a plurality of discrete and separate beads 320 that are arranged to surround the conduit 40. Each of the beads 320 includes a central passage or hole 122 sized to receive the microduct conduit 40. The
15 diameter of the hole 122 is, preferably, slightly larger than the outer diameter of the conduit 40 so that there is a clearance or gap 121 between the conduit 40 and an inner surface 124 of the beads 320 defined by the hole 122. This permits movement of each of the beads 320 laterally or transversely relative to the elongate conduit 40.

20

The beads 320 comprise two segments 330, 332, which may have any of the forms of segment as described above, and fully surround the optical fibre cable 110 forming the protective outer structure 118 and providing the required crush resistance to the optical fibre cable. Although not illustrated, in some embodiments
25 an outer sheath may be provided around the outside of the beads 320 as described above, in order to hold the bead segments together. Alternatively, the bead segments may be bonded or glued together.

In this example, the microduct 40 has a single central bore 42 that houses a single
30 optical fibre cable 110. Depending on the relative sizes of the microduct bore 42 and optical fibre cable, more than one optical fibre cable may fit inside the bore. Often the microduct bore 42 will have space to accommodate additional optical

fibre cables 110, which may be inserted down the length of the bore 42 after the initial underwater installation of the armoured sleeve 114. The microduct 40, therefore, provides a conduit for at least one optical fibre cable 110 and the beads 320 form the outer protective structure 118 and are sized to fully surround the microduct 40. Depending on the particular application, the beads 320 may be secured around the microduct 40 before or after the optical fibre cable 110 is inserted through the bore 42 of the microduct 40.

In each of these embodiments, the conduit, in the form of a retaining optical fibre sheath 16 or a microduct 40, comprises a single bore. In other embodiments, however, it will be appreciated that the conduit may include more than one bore, with each bore receiving and housing one or more optical fibres 12, 112, or one or more optical fibre cables 10, 110, as the case may be.

Additionally, the conduit, either a sheath 16 or a duct 40, may be in the form of bend limiting tubing. This type of tubing is designed such that the bend resistance increases sharply when the bend radius is reduced below a minimum acceptable bend radius consistent with protecting the optical fibre held within the tubing and limiting optical losses stemming from the bend.

Figure 6 illustrates a further embodiment of an armoured optical fibre cable 201 having an armoured sleeve 214 in which beads 420 surround a duct 140 which houses an optical fibre cable 210 and a toning wire 46. The toning wire is embedded within or closely surrounded by a tube of polymeric material that extends continuously with a parallel tube of the same polymeric material that provides a duct 140. The duct may be a microduct, and includes a first bore 142 that houses at least one optical fibre or optical fibre cable. In this example, the duct holds a single optical fibre cable 210 that has the same form as the optical fibre cable of Figures 4 and 5, and so will not be described in detail again. The toning wire 46 is held within a second bore 50, parallel to but separated from the first bore 142, that houses the toning wire. The toning wire 46 may be used to detect the location of the optical fibre cable 210 when the assembled

armoured optical fibre cable 201 is buried, as is well known in the art.

In this embodiment the beads 420 are preferably the same as those of the previous embodiment, shown in Figure 5, and, as such, have a generally annular cross-sectional shape with an axially extending passage 222. The use of these
5 beads 420 has the advantage that the duct 140 is able to twist and rotate freely within the passage 222 of the beads 420. In other embodiments it may be desirable, however, to form the beads so that the passage is generally oval or rectangular so that there is less free space within the passage and the duct 140 is
10 not able to rotate with respect to the surrounding beads.

In embodiments in which it is necessary or desirable to use an optical fibre cable having a greater tensile strength, a number of additional strength members (not shown) may be incorporated in the armoured sleeve. In particular, glass fibre or
15 Kevlar (RTM) strength members or steel wires may be laid between the inner conduit and the outer protective structure along the length of the armoured sleeve.

Figure 7 illustrates an alternative embodiment of the armoured optical fibre cable 301 of the present invention having single-piece beads 520. The protective beads
20 520 are in the form of a bead having a substantially C-shaped cross-section in a plane perpendicular to the axis or length of the conduit to be protected by the beads, such that each bead includes a narrowed opening 52 leading to the passage 322.

25 In this example, the conduit is an external layer 216 of an optical fibre cable 210 similar to the embodiments described above, and so will not be described again in detail.

The opening 52, proximate an external surface 128 of the bead 520, has a width
30 which is slightly smaller than the external diameter of the conduit 216, while the passage 322 has a width which is slightly greater than the diameter of the conduit 216.

The beads 520 are each coupled to the conduit 216 by pressing the opening 52 against the conduit 216 so that the conduit deforms to pass through the opening 52 and into the passage 322. As such, in this embodiment, the elongate conduit 216 must be resiliently compressible at least to the extent needed to perform this operation.

Once the conduit 216 has passed through the opening 52, the conduit 216 returns to its original shape and is seated within the passage 322. The increased width of the passage 322, relative to the opening 52, means that the bead 520 is able to move with respect to the conduit 26 once the bead is secured around the conduit. The reduced width of the opening 52 relative to the passage 322 acts as a retaining feature so that the bead 520 remains secured or clipped to the conduit 216.

This design of bead 520 allows the beads to be coupled or clipped to the conduit 216 quickly and easily, without needing to assemble two or more segments as described above, which may include gluing or bonding of segments together. The use of a single piece bead 520 that can be quickly clipped to the conduit 216 has the advantage that the beads may be secured to the conduit at the point of deployment of the armoured optical fibre cable 301, rather than the armoured sleeve 314 needing to be pre-formed and then transported to the required location.

The opening 52 does, however, mean that the beads 520 do not fully surround the conduit 216 and a section of the conduit is, therefore, not covered by a protective bead. This uncovered section may be vulnerable to damage. However, because the passage 322 has a width which is slightly greater than the diameter of the conduit 216, the beads 520 are able to rotate with respect to each other and to the conduit. It is, therefore, unlikely that the openings 52 in neighbouring beads 520 will remain aligned thereby decreasing the likelihood that the underlying conduit 216 will be damaged.

In all the foregoing embodiments the beads have been loosely spaced apart along the length of the conduit so that they are free to move with respect to each other and to the conduit. In other embodiments the beads may be spaced apart along the conduit and may be bonded to the conduit so that they do not move with
5 respect to each other or to the conduit. In these embodiments the distance between the beads is determined based on the required crush resistance and the minimum radius of curvature to which the armoured optical fibre cable will be bent in use.

- 10 Furthermore, all the embodiments described above have comprised beads made from non-metallic materials.

The present invention, therefore, provides a cost effective armoured sleeve providing crush resistance to an optical fibre that overcomes many of the
15 disadvantages of prior art armoured cables.

CLAIMS

1. An armoured sleeve for surrounding and providing underwater protection to a length of optical fibre, the armoured sleeve comprising:
 - 5 - a protective polymeric inner layer that provides an elongate conduit for holding an optical fibre; and
 - around said inner layer a protective outer structure comprising a plurality of discrete non-metallic beads, each bead having a passage therethrough and the conduit being retained within said passages,
- 10 wherein the beads are positioned in proximity with one another along the length of the conduit to provide crush protection along the length of the conduit, the beads having sufficient density that the armoured sleeve sinks in water.
2. An armoured sleeve as claimed in Claim 1, in which the beads are
- 15 positioned adjacent one another along the length of the conduit to provide crush protection continuously along the length of the conduit.
3. An armoured sleeve as claimed in Claim 1 or Claim 2, in which the beads
- 20 are moveable along the length of the conduit and with respect to one another.
4. An armoured sleeve as claimed in any preceding claim, in which the beads are loosely spaced apart along the length of the conduit, whereby water can flow freely between said beads and into said passages when the armoured sleeve is immersed in water.
- 25 5. An armoured sleeve as claimed in Claim 4, in which the beads are made of glass.
6. An armoured sleeve as claimed in any preceding claim, in which the conduit
- 30 is bend limiting tubing.
7. An armoured sleeve as claimed in any preceding claim, in which the

protective outer structure further comprises an outer sheath extending continuously along the length of the conduit, said plurality of beads being held between the outer sheath and the conduit.

5 8. An armoured sleeve as claimed in Claim 7, in which the outer sheath is elastomeric and at least partially conforms to an undulating external shape of said beads.

9. An armoured sleeve as claimed in any preceding claim, in which each bead
10 has a channel therethrough, the channel leading to said passage and the channel having a width less than a corresponding diameter of said passage.

10. An armoured sleeve as claimed in any one of Claims 1 to 8, in which each bead comprises two separate abutting segments, said segments extending on
15 opposite sides of the conduit and each of said segments having a pair of abutting surfaces adapted to abut against a corresponding pair of abutting surfaces on the other one of said segments,

11. An armoured sleeve as claimed in Claim 10, when dependent from Claim 7
20 or Claim 8, in which the outer sheath holds said abutting segments together.

12. An armoured sleeve as claimed in Claim 10 or Claim 11, in which said abutting surfaces are substantially planar, said planar surfaces being parallel with an axis of the elongate conduit.

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13. An armoured sleeve as claimed in Claim 10 or Claim 11, in which said abutting surfaces are substantially planar, said planar surfaces being set at an angle with an axis of the elongate conduit.

30 14. An armoured sleeve as claimed in any one of Claims 10 to 13, in which each said two separate segments are interchangeable with each other such that any two segments may be used to form any one of said beads.

15. An armoured sleeve as claimed in any one of Claims 10 to 14, in which said abutting surfaces in contact between the two separate segments of each bead include an interengaging feature.

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16. An armoured sleeve as claimed in Claim 15, in which said interengaging feature is a tongue and groove formation.

17. An armoured sleeve as claimed in Claim 16, in which tongue and groove
10 formation of each of said segments is one side of a conduit axis a tongue and on the other side of the conduit axis is a groove.

18. An armoured sleeve as claimed in any one of Claims 9 to 17, in which the protective outer structure comprises an outer sheath that extends along the length
15 of the conduit, said sheath compressing and holding said abutting bead segments together.

19. An armoured optical fibre cable comprising an armoured sleeve as claimed in any preceding claim, and at least one optical fibre extending through the
20 elongate conduit.

20. An armoured optical fibre cable as claimed in Claim 19, in which the conduit is a sleeve of an optical fibre cable.

25 21. An armoured optical fibre cable as claimed in Claim 19, in which the conduit is a duct inside of which is loosely held at least one optical fibre cable.

22. A method of constructing an armoured sleeve for protecting a length of optical fibre, the armoured sleeve comprising a protective polymeric inner layer
30 that provides an elongate conduit having at least one bore for receiving a length of optical fibre and having a density insufficient such that the conduit will sink in water, and a plurality of discrete beads, each of said beads having a passage

therethrough for receiving a part of the conduit, the method comprising the steps of:

- i) securing a first one of said beads around the conduit;
- ii) securing a second one of said beads around the conduit directly adjacent to the first bead such that the first and second beads are non-interconnected; and
- iii) repeating steps i) and ii) along a length of the conduit such that beads are positioned in proximity with one another along the length of the conduit to provide crush protection along said length of conduit and to provide sufficient weight around the conduit such that that the armoured sleeve will sink in water.

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23. A method as claimed in Claim 22, in which the elongate conduit is resiliently compressible and each bead is substantially C-shaped in cross-section whereby the bead has a narrowed opening leading to the passage, the method comprising the step of securing each bead to the conduit by pressing the bead over the conduit so that the conduit is resiliently compressed as the conduit passes through the opening until the conduit enters the passage.

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24. A method as claimed in Claim 22 , in which each of the beads comprises two separate abutting segments, each of said segments having a pair of abutting surfaces adapted to abut against a corresponding pair of abutting surfaces on the other one of said segments, and the step of securing each bead to the conduit comprises positioning a first one of said segments against the elongate conduit with a first one of said abutting surfaces on an opposite side of the conduit from a second one of said abutting surfaces and positioning a second one of said segments against the elongate conduit with a third one of said abutting surfaces in abutting contact with said first abutting surface and with a fourth one of said abutting surfaces in abutting contact with said second one of said abutting surfaces.

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25. A method as claimed in Claim 24, in which said abutting surfaces in contact between the two separate segments of each bead include an interengaging feature, the method comprising the step of using said interengaging features to

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locate said two separate segments relative to each other.

26. A method as claimed in Claim 24, in which said abutting surfaces in contact between the two separate segments of each bead include an interlocking feature,
5 the method comprising the step of using said interlocking feature to hold said two separate segments together in alignment with each other.

27. A method as claimed in any of Claims 22 to 26, in which the method further comprises covering the beads with an outer sheath that extends continuously
10 along the length of the conduit.

28. A method as claimed in any of Claims 24 to 26, in which the method further comprises covering the beads with an outer sheath that extends along the length of the conduit, and using the outer sheath to hold the abutting surfaces of the
15 abutting bead segments together.

29. A method as claimed in Claim 27 to Claim 28, in which the outer sheath is made from an elastomeric material, the method comprising the step of applying the outer sheath around the beads along the length of the conduit so that the
20 sheath at least partially conforms to an external shape of the beads, whereby said sheath compresses said abutting bead segments together.

30. A method of constructing an armoured optical fibre cable comprising an armoured sleeve and at least one optical fibre protected within said sleeve, the
25 method comprising the steps of constructing the armoured sleeve according to the method of any one of Claims 22 to 29, and further comprising the step of inserting said optical fibre through said bore of the conduit, the beads being secured around the conduit either before or after the optical fibre cable is inserted through said bore of the conduit.

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31. A method of installing an armoured optical fibre cable in a body of water, the body of water having a floor and the armoured optical fibre cable being as

claimed in any one of Claims 19 to 21 or being constructed according to the method of Claim 30, comprising the steps of:

- i) placing a length of the armoured optical fibre cable in said body of water; and
- 5 ii) allowing the armoured optical fibre to sink in the water under its own weight and thereby laying the armoured optical fibre on the floor of said body of water.

32. A method as claimed in Claim 31 further comprising the steps of:

- 10 iii) forming a trench in the floor of said body of water into which trench said armoured optical fibre cable is laid; and
- iv) back-filling said trench to bury the armoured optical fibre in said trench, the plurality of beads providing crush resistance within said back-filled trench.

15 33. An armoured sleeve substantially as herein described with reference to, or as shown in, the accompanying drawings.

34. An armoured optical fibre cable substantially as herein described with reference to, or as shown in, the accompanying drawings.

20 35. A method of constructing an armoured sleeve substantially as herein described with reference to the accompanying drawings.



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Claims searched: 1-21 & 31-32

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Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-3, 5-6, 9, 19-22, 27 & 29-32	US5197767 A (KIMURA et al) See abstract and figures noting universal, flexible, waterproof protective outer structure for cables with beads 6.
X	1-3, 5-9, 11, 18-22, 27 & 29 - 32	US5143123 A (RICHARDS et al) See abstract & figures, especially figures 2a, 2b & 4, noting flexible armour for fibre optic cable, armour links/beads 10 made from metal with a hard coating to prevent corrosion, & outer thermoplastic material sheath 22 holding links in place as defined in column 3 lines 24-43.
X	1-2, 5, 7, 22-23, 27 & 30-32	DE3110008 A1 (SIEMENS) See abstract and figures noting beads 20, 30, electrical cable conduit 10 and outer sheath 25
A	-	US4696542 A (THOMPSON) See abstract and figures noting flexible armoured optical fibre cable with a plurality of armour wires 32.
A	-	WO2007/022117 A2 (TYCO TELECOMMUNICATIONS (US) INC.) See abstract and figures noting fibre optic cable designed for use in an undersea environment noting armour wire members 132.
A	-	US4239336 A (PARFREE et al) See abstract and figures noting tube 1 with joint in cladding that is welded or soldered shut along two adjacent abutting surfaces.
A	-	DE3201573 A1 (SIEMENS) See abstract and figures noting outer sheath with abutment surfaces with planar or tongue and groove interconnecting means.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.



Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

G02B

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC & Internet

International Classification:

Subclass	Subgroup	Valid From
G02B	0006/44	01/01/2006