(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 June 2003 (12.06.2003)

PCT

(10) International Publication Number
WO 03/048809 A2

(51) International Patent Classification[7]: G01V

(21) International Application Number: PCT/US02/38387

(22) International Filing Date: 2 December 2002 (02.12.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/334,284 30 November 2001 (30.11.2001) US

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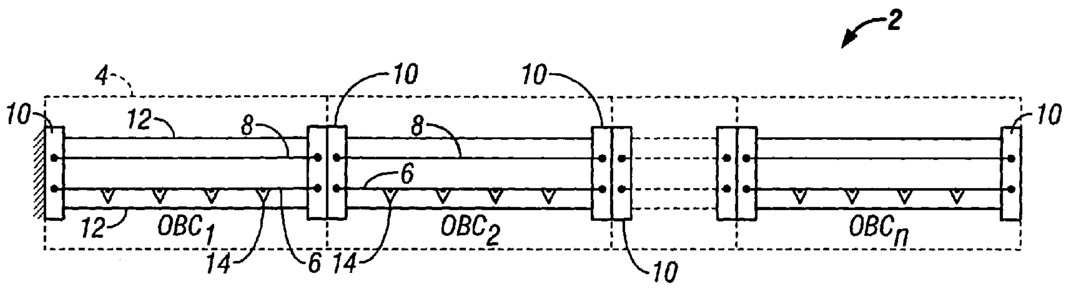
(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: PERMANENTLY INSTALLED SEISMIC OCEAN BOTTOM CABLE



(57) Abstract: A seismic ocean bottom cable array is provided for use in subsurface exploration. The array includes receiver stations for measuring seismic signals, and a cable including conductors for data transmission and an externally attached stress member. The array is assembled during deployment by attaching the data transmission cables and receiver stations to the stress member as it is lowered into the water.

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PERMANENTLY INSTALLED SEISMIC OCEAN BOTTOM CABLE

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FIELD OF THE INVENTION

The invention relates to ocean bottom cable arrays (OBC arrays) used in marine seismic surveys and in particular to OBC arrays adapted for permanent placement on the ocean floor.

DESCRIPTION OF THE RELATED ART

Marine seismic exploration surveys are conducted in two ways: seismic sensors (e.g. pressure sensors, motion sensors, or a combination of both) are deployed behind a vessel and towed just below the ocean surface, or they are deployed and placed on the ocean floor. A survey where sensors are placed on the ocean floor is often referred to as an ocean bottom seismic (OBS) survey. The OBS survey involves the steps of: placing an OBC array, collecting data, and the optional step of retrieving the OBC array.

The OBC array **2**, as shown schematically in FIG. 1(a) is generally comprised of one or more ocean bottom cables (OBCs) **4** that are mechanically and electrically connected together. OBCs are generally constructed with a plurality of electrical or optical conductors **6** for transmitting signals, one or more stress members **8** for transmitting axial forces along the OBC, connectors **10** for terminating the conductors and stress members at each end of the OBC and transmitting electrical signals and mechanical forces between OBCs, a waterproof jacket **12** that surrounds the conductors and stress members, and one or more receiver stations **14** each having one or more seismic sensors. The receiver stations usually contain the sensors in a hermetically sealed housing. The receiver station is often rigidly attached to the OBC such that it is designed to survive deployment and retrieval operations without encountering mechanical or electrical failure.

The stress member is designed to provide the primary axial load carrying capability of the OBC. The stress member is generally manufactured into the OBC construction such that it is integrated into the OBC and the OBC is handled as a single unit when it is loaded onto a vessel and later deployed. A problem with this approach is the size and weight of the integrated OBC and the size and complexity of the handling equipment required to deal with the cable.

Each end of the OBC typically has a connector that terminates the ends of the conductors and stress members at substantially the same point so that multiple OBCs may be connected end-to-end to create an OBC array. An OBC of this type is seldom longer than 200 meters. An OBC array comprised of this type of OBC does not have a continuous conductor or stress member along its length because the conductors and stress members terminate simultaneously at spaced apart connectors along the length of the OBC array.OBCs have long been constructed to survive many deployment and retrieval operations. Deployment and retrieval specifications normally require that an OBC be mechanically robust, because it must support it's own weight in tension while being waterproof and carrying the required number of conductors. Terminations and connectors for OBCs tend to be bulky and therefore complex to design, expensive and prone to failure.

A consequence of the traditional OBC construction is the cable's high mechanical rigidity. The high rigidity allows noise transmitted into one part of the OBC to migrate throughout the cable to receiver stations along the cable, reducing the system signal-to-noise ratio. In particular, stress members provide an ideal path for noise transmission. Traditional OBCs with receiver stations that are rigidly coupled to the cable provide little or no damping mechanism between the cable and the receiver station.

A desirable OBC includes receiver stations that are rigidly coupled to the cable during deployment, but become significantly decoupled prior to a survey such that signal-to-noise ratio is improved.

OBCs are also used for reservoir monitoring, where multiple surveys are conducted in the same area over a period of years. OBCs may be deployed and retrieved for each survey or they may be permanently left at the survey location. Permanently placed OBCs have the advantage of not requiring a retrieval step. Retrieval processes usually place more forces on an OBC than deployment processes. Therefore, the traditional OBC is commonly overdesigned for permanent placement. A simple and inexpensive OBC is desirable for permanent placement at the ocean bottom to perform seismic surveys and reservoir monitoring.

SUMMARY OF THE INVENTION

This invention provides an OBC array embodying features of the invention including one or more conductor cables, a plurality of receiver stations coupled to the conductor cables, and a stress member coupled externally to the conductor cables.

In a preferred embodiment, the stress member may be substantially continuous along the length of the OBC array. In another embodiment, the OBC array may include a layer of material that surrounds the stress member and the seismic cable. In another embodiment, the layer may be a yarn braid or an extruded thermoplastic.

Also in accordance with the invention a method is provided of deploying a marine seismic array from a vessel into a body of water. The method includes the steps of deploying a continuous stress member from the vessel and attaching a seismic cable to the stress member before the seismic cable and the stress member are deployed into the body of water. The method of attaching the cable to the stress member may be done optionally on the vessel. The method of attaching may further include applying a braid around the stress member and the seismic cable. The method may also be done by feeding the stress member and the seismic cable into a braiding system.

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description, taken in conjunction with the accompanying drawings, and its scope will be pointed out in the appending claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A-1C are a side view of an ocean bottom cable.

FIG. 2 is a side view of a receiver station attached to the ocean bottom cable.

FIG. 3 is a top view of the receiver station of FIG. 1C.

FIG. 4 is a cross-section view of the ocean bottom cable shown in FIG. 2.

FIG. 5 is a side view of a vessel with OBC deploying equipment.

FIG. 6 is a side view of an alternative embodiment of OBC deploying equipment.

DESCRIPTION

An improved OBC array **16** is represented schematically in FIG. 1(b). The OBC array includes a stress member **18** with first and second ends **20** & **22**. Conductor cables **24** include receiver stations **26** at spaced apart locations and are coupled end-to-end with electrical connectors **28** that transmit electrical or optical signals between the conductor cables. As opposed to prior art designs, electrical and mechanical terminations are not necessarily co-located as in FIG. 1(a) in order to assemble the OBC array.

An OBC array **100** is also shown in FIG. 1(c) and includes multiple, spaced apart receiver stations **102** positioned along a cable **104**. FIG. 2 shows an exemplary version of the receiver station **102** attached to the cable **104**. Referring to FIG. 2 and FIG. 4, the cable **104** includes a stress member **202**, a first conductor cable **204**, and a second conductor cable **206**. The stress member **202** provides substantially all of the axial load bearing capacity for the cable **104**. The first conductor cable **204** and the second conductor cable **206** are both constructed of multiple, insulated, electrical and/or optical conductors surrounded by an extruded waterproof jacket. The stress member **202** is preferably external to the first conductor cable **204** and the second conductor cable **206** such that the first conductor cable **204** and the second conductor cable **206** are constructed independently of the stress member.

Ocean bottom cables are traditionally attached end-to-end by connectors that transmit electrical signals from electrical conductors in one ocean bottom cable to electrical conductors in another ocean bottom cable. Connectors generally also transmit mechanical forces held by internal stress members between two connected ocean bottom cables. Ocean bottom cables with internal stress members are traditionally expensive and complex in part because the connectors must terminate stress members and conductors. A benefit of an external stress member is that it may terminate at a point independent from an electrical conductor termination. In other words, a stress member **202** may terminate at a connector that does not terminate a conductor. The external stress member may be of any length independent of the electrical conductor length. In a preferred embodiment, the stress member **202** terminates only at each end of the OBC array **100** and is therefore substantially continuous along the OBC array **100**. A continuous length of the stress member **202** may be up to 10-15 kilometers and would significantly reduce the number of connectors and simplify their design.

The stress member **202** may be constructed of synthetic fiber or steel and is preferably continuous along the length of the cable **104**. The first conductor cable **204** and the second conductor cable **206** are secured to each other by an inner braid **400**. The inner braid **400** is preferably a yarn material that is wound around the cables. Alternatively, the first conductor cable **204** and second conductor cable **206** may be secured by other means such as an extruded layer of thermoplastic or thermoset material. The cables may also be secured by discrete clamps spaced along the length of those cables. The stress member **202** is secured to the first conductor cable **204** and second conductor cable **206**. The outer braid **200** surrounds the cables and the stress member **202** and is also preferably a yarn material.

Referring to FIG. 2 and FIG. 3, the receiver station **102** includes a mechanical coupling member **208** that mechanically connects the stress member **202** to the receiver housing **210**. A retainer **214** couples the mechanical coupling member **208** to the stress member **202**. The retainer **214** also couples the first conductor cable **204** and the second conductor cable **206** to the mechanical coupling member **208**.

The mechanical coupling member optionally disengages the cable **104** from the receiver housing **210** after the receiver housing **210** is deployed. The action of disengaging may be enabled through a number of different methods. The member may be made of a material that degrades in the presence of seawater, for example, certain polyurethanes. The member may be made from a material such that application of a chemical to the member would cause the member material to degrade. The member may be made of a material that has a low melting point and the member is electrically heated in situ to physically melt the material. Such a material may be a thermoplastic or a low melting-point metal such as powder metal manufactured by Serra™. Such a metal is heated to melting points of 175 °F or higher using an electrical source of heat. The member may also be a material that acts as an anode in a galvanic reaction and would thus dissolve in seawater. The member may also be made of a material that is designed to oxidize in the presence of sea water such as aluminum. The member may also be mechanically actuated to detach the receiver station from the seismic cable.

Referring back to FIG. 1(b), the OBC array may generally be assembled using coupling member **30** to attach the stress member **18** to the receiver station **26**, the electrical connector **28**, or the conductor cable **24**. In this fashion, the OBC array may be optimally assembled depending on the operating conditions.

The receiver housing **210** includes one or more seismic sensors such as a hydrophone, geophone, or accelerometer and may include electronics for filtering and digitizing signals from the one or more seismic sensors. An output signal from the receiver housing **210** is coupled to the second conductor cable **206** through connectors **212**. The receiver housing **210** is preferably cylindrical in shape and its longitudinal axis is preferably aligned with the cable **104** longitudinal axis.

The embodiment as described above is an inexpensive array to manufacture and deploy compared to prior art systems in which the stress member is manufactured into the seismic cable. Because the stress member is coupled externally to the seismic cable, the telemetry and second conductor cables may be assembled separately from the stress member. The embodiment eliminates a need for expensive cable manufacturing equipment and allows the designer to select an inexpensive stress member. The embodiment also reduces the typical number of electrical and mechanical terminations found in the array. Traditional systems use custom connectors that are designed to terminate electrical or optical conductors at the receiver housing while transferring axial mechanical loads to the receiver housing. The continuous stress member eliminates the need to transfer loads through the housing and results in a simple connector design.

Referring to FIG. 5 and FIG. 6, a seismic cable deployment system **500** is shown. A vessel **502** deploys a seismic cable **506** from a storage bin **504** into a body of water **516**. The vessel **502** may be of the type that is typically used for deployment and retrieval of ocean bottom seismic cables. The seismic cable **506** includes one or more receiver stations **518** and one or more conductor cables. The storage bin **504** is used to secure the seismic cable **506** on the vessel deck, but the same function may be accomplished using a reel.

The stress member **202** is unwound from a reel **508** over a sheave **512** and is attached to the seismic cable **506**. The sheave **512** is preferably at least 3 meters in diameter. A wire tensioner **602** deploys the seismic cable **506** from the storage bin **504**.

The wire tensioner **602** is a two-wheel wire winch that preferably controls the cable deployment speed from 0 – 20 meters/minute. As the wire tensioner **602** deploys the seismic cable **506**, the reel **508** deploys the stress member and maintains a tension force on the stress member **202** such that the reel bears most of the weight of the seismic cable 506 as it is deployed Optionally, the stress member **202** may be deployed from a storage bin that is not shown. In that case, a back-tensioner must then be used to provide the tension force.

Again referring to FIG. 5 and FIG. 6, a braiding system **514** attaches the seismic cable **506** to the stress member **202** while simultaneously deploying both. The braiding system **514** is well known in the art of cable manufacturing. The braiding system **514** may preferably be placed in the deployment system such that the stress member and seismic cable are joined just before entering the water. In this fashion, the seismic cable experiences minimal tensile or bending forces. Reduced forces allow the cable and connector design to be relatively simple and inexpensive.

The resulting OBC array and deployment system are designed for cost-effective manufacturing and deployment. As opposed to simultaneous deployment, the seismic cable **506** and stress member **202** may optionally be joined at a location not on the vessel and subsequently loaded onto the vessel for deployment. While the OBC array is ideally intended for permanent placement on the ocean bottom, these concepts may be applied to a retrievable cable design.

Although the invention has been described in detail in the reference to a preferred version, other versions are possible. Therefore, the spirit and scope of the claims should not be limited to the preferred version described in detail.

CLAIMS

What is claimed is:

1. An OBC array comprising:
   (a) one or more conductor cables,
   (b) a plurality of spaced apart receiver stations coupled to the one or more conductor cables, and
   (c) a stress member coupled externally to the one or more conductor cables, wherein the stress member is substantially continuous along the length of the OBC array.
2. The OBC array of claim 1 further comprising a layer of material that surrounds the stress member and the one or more conductor cables.
3. The OBC array of claim 2 wherein the layer is a yarn braid.
4. The OBC array of claim 2 wherein the layer is an extruded thermoplastic.
5. The OBC array of claim 1, further comprising a mechanical coupling member for rigidly coupling the receiver station and the OBC array wherein the member disengages the receiver station from the OBC array during or after deployment of the OBC array.
6. The OBC array of claim 5, wherein the member disengages the receiver station from the seismic cable by a method selected from the group consisting of:
   (a) the member degrades in the presence of seawater,
   (b) the member degrades following the application of a chemical, and
   (c) the member is actuated to mechanically detach the receiver station from the seismic cable.
7. A method of deploying an OBC array from a vessel into a body of water comprising:
   (a) deploying a stress member into the body of water, and
   (b) attaching a seismic cable to the stress member before the seismic cable and the stress member are deployed into the body of water.
8. The method of claim 7, wherein the attaching step occurs on the vessel.
9. The method of claim 7, wherein the method of attaching further includes applying a braid around the stress member and the seismic cable.
10. The method of claim 8, wherein the method of attaching is accomplished by feeding the stress member and the seismic cable into a braiding system.

11. A method of deploying an OBC array comprising:
    (a) providing a seismic cable and a plurality of spaced apart receiver stations, and
    (b) attaching a stress member externally to the seismic cable to form the OBC array.
12. The method of claim 11, wherein the OBC array is deployed into a body of water for performing a seismic survey.
13. The method of claim 11, wherein a yarn braid is applied to the seismic cable and the stress member before deploying the OBC array.
14. An OBC array comprising:
    (a) a seismic cable including one or more conductor cables and a stress member,
    (b) a receiver station coupled to the seismic cable, and
    (c) a mechanical coupling member for rigidly coupling the receiver station and the seismic cable wherein the member disengages the receiver station from the seismic cable during or after OBC array deployment.
15. The OBC array of claim 14, wherein the member disengages the receiver station from the seismic cable by a method selected from the group consisting of:
    (a) the member degrades in the presence of seawater,
    (b) the member degrades following the application of a chemical, and
    (c) the member is actuated to mechanically detach the receiver station from the seismic cable.
16. A system for deploying a seismic cable comprising:
    (a) a first device for providing a stress member, wherein the device deploys the seismic cable by holding a tension force on the stress member,
    (b) a second device for providing a seismic cable, and
    (c) a third device for assembling and deploying the stress member and the seismic cable.
17. The system of claim 16, wherein the stress member and the seismic cable are assembled and deployed simultaneously.
18. The system of claim 16, wherein the stress member and the seismic cable are assembled at a first time and deployed at a subsequent time.
19. A method for simultaneous assembly and deployment of a seismic cable comprising:
    (a) providing a stress member,

(b) providing a conductor cable,

(c) assembling the stress member and the conductor cable to form the seismic cable, and

(d) deploying the seismic cable.

20. The method of claim 19, wherein the steps of assembling and deploying occur simultaneously.

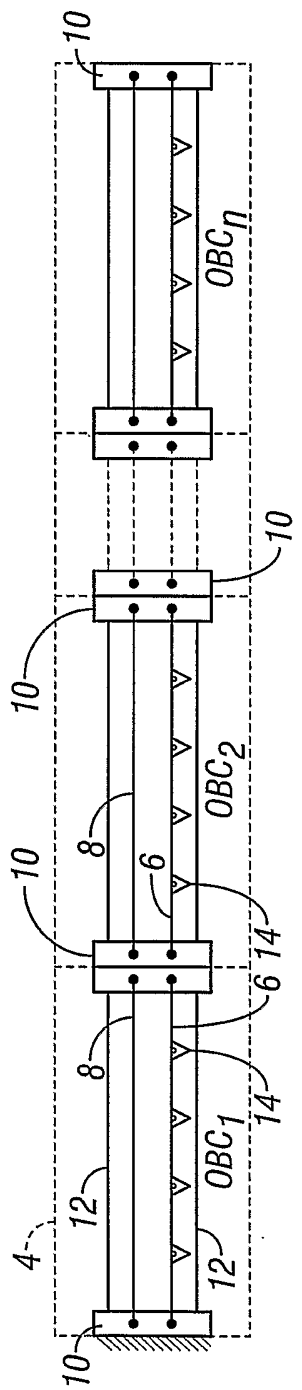

FIG. 1A
(Prior Art)

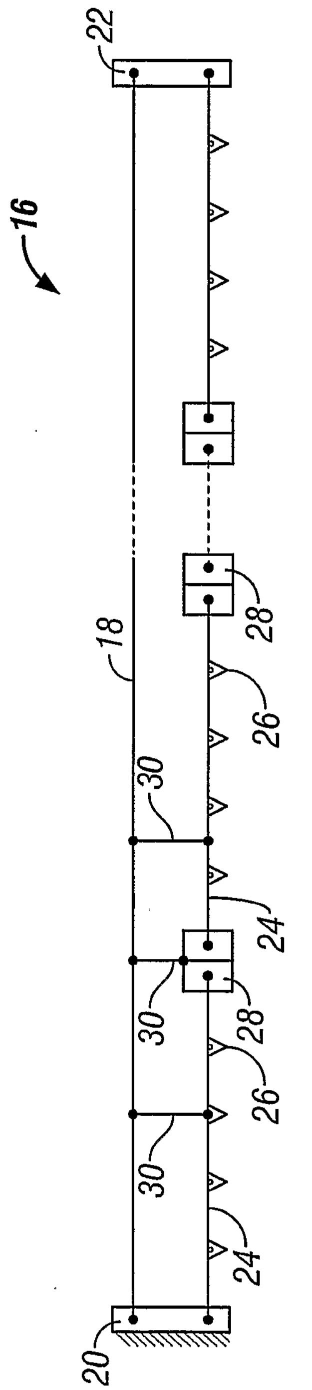

FIG. 1B

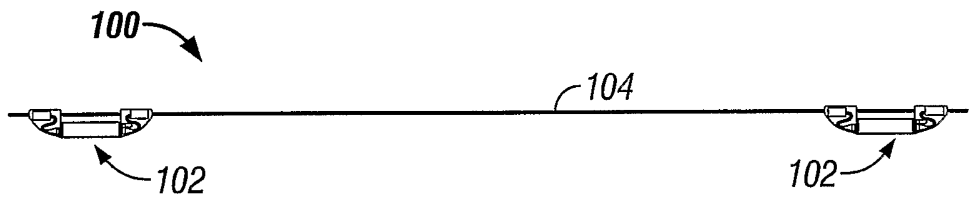

FIG. 1C

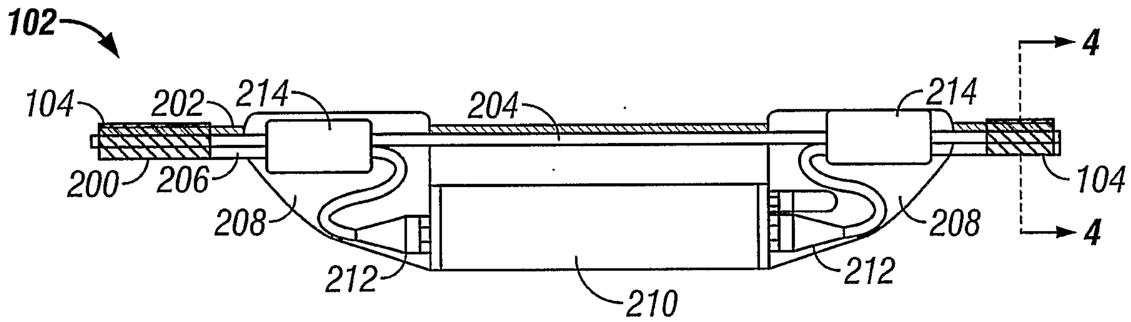

FIG. 2

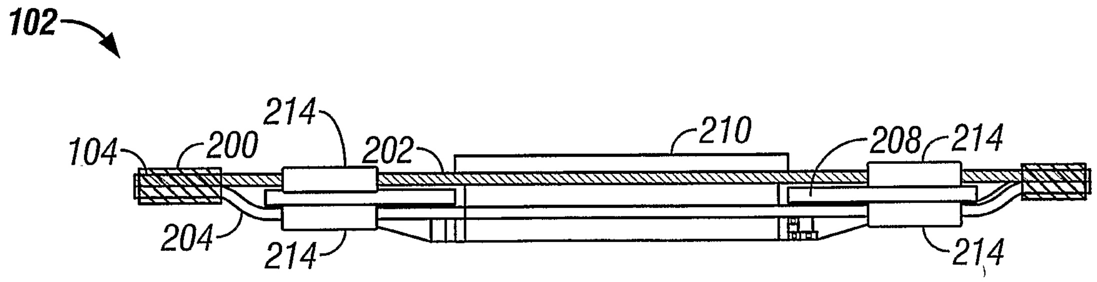

FIG. 3

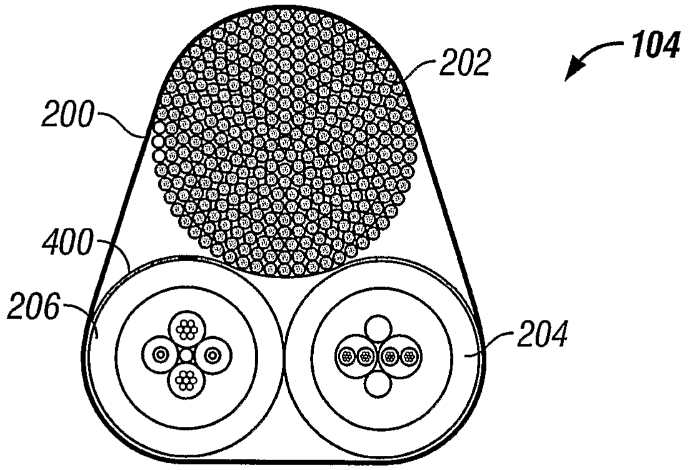
104
202
200
400
206
204

FIG. 4

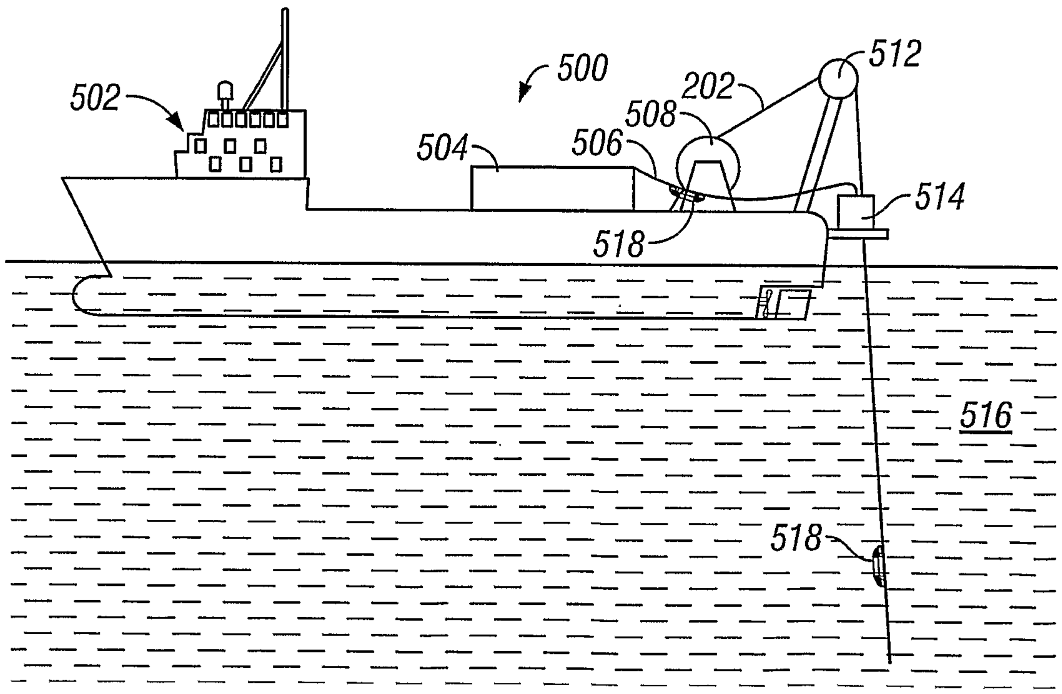
512
500
202
502
508
504
506
514
518
516
518

FIG. 5

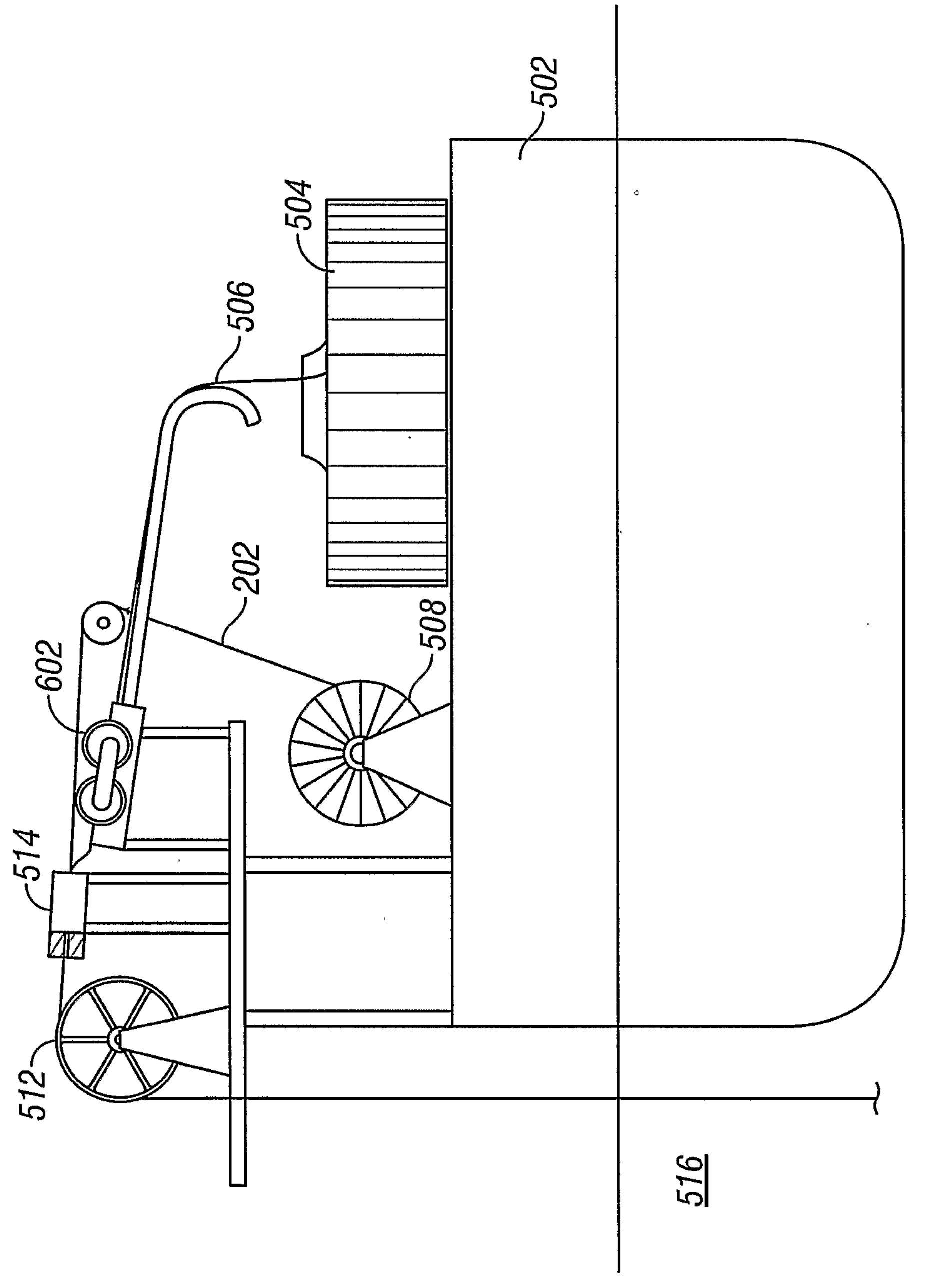

FIG. 6