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(54) Title: INSTALLING CABLES IN BOREHOLES BY AN EVERTING LINER

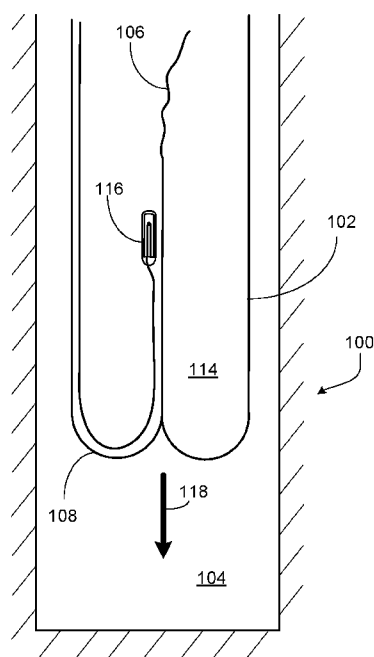


FIG. 1B

(57) Abstract: A borehole (104) is traversed through by an everting liner (102) from an upper end of the borehole to substantially a lower end of the borehole. A cable (108) attached to the everting liner (102) is carried into the borehole. A tether (106) attached to the everting liner (102) is carried into the borehole. The tether (106) is attached to an end of the everting liner (102) that is configured to be at the downhole end of the borehole after traversing the borehole.

INSTALLING CABLES IN BOREHOLES BY AN EVERTING LINER

CLAIM OF PRIORITY

[0001] This application claims priority to U.S. Patent Application No. 16/025,854 filed on July, 2, 2018, the entire contents of which are hereby incorporated
5 by reference.

TECHNICAL FIELD

[0002] This disclosure relates to everting liners used in boreholes.

BACKGROUND

[0003] An everting liner is used to line a conduit for repair or isolation
10 purposes. The everting liner traverses conduits by turning inside out, also known as everting, and lines the conduit in the process. In other words, the everting liner traverses through itself and presses itself against a wall of the conduit. The traversing process is powered by a pressurized fluid, such as air or water. In some instances, a tether is secured to one end of the everting liner and is configured to traverse through
15 the liner during installation. The tether can be used to reel-in the liner once it is no longer needed.

[0004] Acoustic detection using optical fibers exploits Rayleigh, back scattering along a fiber from a short pulse of light traversing the fiber. The back-scattering characteristics change if the fiber is moved or deformed even on the micron-
20 scale. Thus, a record of changes in scattering intensity as a function of pulse transit time corresponds to movement of the fiber as a function of position along the fiber. This results in a distributed acoustic sensor that can be used for well diagnostics in the oil field on either a temporarily or a permanently installed basis. Such fiber based sensors can be used to detect the acoustic signature of small leaks, flows, and bubbles
25 within a wellbore or borehole.

SUMMARY

[0005] This disclosure describes technologies relating to installing cables in boreholes with an everting liner.

[0006] An example implementation of the subject matter described within this
30 disclosure is a method performed by an everting liner with the following features. A borehole is traversed through from an upper end of the borehole to substantially a lower end of the borehole. A cable attached to the everting liner is carried into the

borehole. A tether is attached to the everting liner is carried into the borehole. The tether is attached to an end of the everting liner that is configured to be at the downhole end of the borehole after traversing the borehole.

[0007] Aspects of the example implementation, which can be combined with the example implementation alone or in combination, include the following. An acoustic coupling medium is received into the everted liner.

[0008] Aspects of the example implementation, which can be combined with the example implementation alone or in combination, include the following. The acoustic coupling medium includes cement, sand, bentonite, or water.

[0009] Aspects of the example implementation, which can be combined with the example implementation alone or in combination, include the following. The cable is deformed by an acoustic wave passing through the cable.

[0010] Aspects of the example implementation, which can be combined with the example implementation alone or in combination, include the following. The borehole is traversed out of by the everting liner. A cable is carried out of the borehole.

[0011] Aspects of the example implementation, which can be combined with the example implementation alone or in combination, include the following. A cement cap is received at an upper end of the liner.

[0012] An example implementation of the subject matter described within this disclosure is a system with the following features. An everting liner is configured to evert during installation. The everting liner is configured to be installed in a borehole. A central tether is attached to an end of the everting liner. The tether is configured to retrieve the everting liner after installation. The tether is configured to travel through the everting liner during installation. A cable is configured to be installed into the borehole with both the everting liner and the central tether. The cable is configured to detect acoustic waves within the borehole.

[0013] Aspects of the example system, which can be combined with the example system alone or in combination, include the following. The cable comprises an optical fiber.

[0014] Aspects of the example system, which can be combined with the example system alone or in combination, include the following. The optical fiber comprises a looped fiber cable. The looped fiber cable includes a turn-around assembly.

[0015] Aspects of the example system, which can be combined with the example system alone or in combination, include the following. The turn-around assembly includes a glass cap defining a space sufficient for a minimum bend radius of the looped fiber cable. The glass cap is configured to protect the fiber.

5 [0016] Aspects of the example system, which can be combined with the example system alone or in combination, include the following. The cable is attached to the tether.

[0017] Aspects of the example system, which can be combined with the example system alone or in combination, include the following. The cable is attached
10 to the liner.

[0018] Aspects of the example system, which can be combined with the example system alone or in combination, include the following. The cable is configured to be between a wall of a borehole and the everted liner once installed.

[0019] Aspects of the example system, which can be combined with the
15 example system alone or in combination, include the following. The liner is configured to be between a wall of a borehole and the cable once installed.

[0020] Aspects of the example system, which can be combined with the example system alone or in combination, include the following. The cable is directly attached to the liner with an adhesive.

20 [0021] Aspects of the example system, which can be combined with the example system alone or in combination, include the following. The liner includes a pocket that runs substantially an entire length of the liner. The cable runs through the pocket.

[0022] Aspects of the example system, which can be combined with the
25 example system alone or in combination, include the following. The cable runs substantially an entire length of the borehole.

[0023] An example implementation of the subject matter described within this disclosure is a system with the following features. An everting liner is configured to evert during installation. The everting liner is configured to be installed in a borehole.
30 A central tether is attached to an end of the everting liner. The tether is configured to retrieve the everting liner after installation. The tether is configured to travel through the everting liner during installation. An optical fiber is attached to and runs a length of the everting liner. The optical fiber is configured to be installed into the borehole

with both the everting liner and the central tether. The cable is configured to be between a wall of a borehole and the everted liner once installed. The cable is configured to detect acoustic waves within the borehole.

[0024] Aspects of the example system, which can be combined with the example system alone or in combination, include the following. The optical fiber includes a looped fiber cable. The looped fiber cable includes a turn-around assembly.

[0025] Aspects of the example system, which can be combined with the example system alone or in combination, include the following. The turn-around assembly includes a glass cap defining a space sufficient for a minimum bend radius of the looped fiber cable. The glass cap is configured to protect the fiber.

[0026] Particular implementations of the subject matter described in this disclosure can be implemented to realize one or more of the following advantages. A cable is protected during conveyance, so a wider variety of protection options can be used for the cable. Conveyance is achieved even through narrow parts of the borehole. One-trip conveyance can be achieved with little risk of borehole collapse. Aspects of this disclosure reduce the chances of bunching or jamming the cable. Conveyance with liner provides superior depth control for the cable compared to conventional methods. After backfill with a coupling fluid, the liner provides hydraulic isolation and prevents cross-flow of water between aquifers that the liner also serves as a carrier of the assembly. Water or air infill provides coupling for the entire length of the borehole, from a lower end of the borehole to an upper end of the borehole. The fiber can be used as seismic sensor with every segment of fiber outputting strain measurements.

[0027] The details of one or more implementations of the subject matter described in this disclosure are set forth in the accompanying drawings and description. Other features, aspects, and advantages of the subject matter will become apparent from the description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] FIG. 1A is a top-down view of an example everted liner and cable installed in a borehole.

[0029] FIG. 1B is a side cross sectional view of an example everting liner installing a cable into a borehole.

[0030] FIG. 1C is a side cross sectional view of an example everting liner installed in a borehole with a cable.

[0031] FIG. 2A is a top-down view of an example everted liner and cable installed in a borehole.

5 [0032] FIG. 2B is a side cross sectional view of an example everting liner installing a cable into a borehole.

[0033] FIG. 2C is a side cross sectional view of an example everting liner installed in a borehole with a cable.

[0034] FIG. 3A is a top-down view of an example everted liner and cable
10 installed in a borehole.

[0035] FIG. 3B is a side cross sectional view of an example everting liner installed in a borehole with a cable.

[0036] FIG. 4 is an example turn-around assembly that can be used with aspects of this disclosure.

15 [0037] FIG. 5 is a flowchart of an example method that can be used with aspects of this disclosure.

[0038] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

20 [0039] Deploying fibers in boreholes is a challenging endeavor in practice for several reasons. First, fiber can be conveyed to the bottom of the borehole. Second, to provide good-quality seismic measurement, fiber has to be in good acoustic coupling or contact with the outside formation, which is typically achieved with backfill, such as cement, sand, bentonite, or water. In the presence of karsts, lost-circulation zones,
25 and other downhole hazards, both conveyance and backfill for coupling becomes challenging and prone to operational delays.

[0040] Separate conveyance of a cable, such as a fiber cable, remains prone to various operational issues. For example, a weighted bar, attached to the end of the cable to assist in lowering the cable, can be stuck along narrow portions of the well.
30 Fiber can become bunched or part of it can become trapped by impinging rocks resulting in loss of optical signal along the fiber. Fiber may be cut by sharp corners of the rocks sticking out from borehole wall when deployed under tension with a weighted bar. If the fiber is not strong, then a separate carrier cable can be used to

carry the weight bar. Conventional conveyance requires additional operational time and carries additional risks that, in turn, are mitigated by using stronger more expensive cables.

[0041] This disclosure relates to a method and apparatus for installing fiber-optic fibers or other cables into a borehole using an everting liner. In one implementation, the optical fiber is attached to an inner portion of the liner ("inner" after installation) so that the cable lies against the liner adjacent to the wall of the borehole. In some implementations, the optical fiber is attached to an outer portion of the liner ("outer" after installation) so that the fiber is in direct contact with the wall of the borehole with the liner pressing the fiber against the borehole wall. In some implementations, the cable is attached to the central tether of the everting liner so that the cable is roughly centered in the middle of the borehole. In all implementations, the liner is filled with water, sand, or a slurry mixture of the two in order to enable acoustic coupling, acoustic attenuation, or a combination, with the borehole. These installation methods can be used for either permanent or temporary installations.

[0042] FIG. 1A shows a top-down view of an example of a liner and cable installed within a borehole. The system 100 includes an everting liner 102 configured to evert during installation. Details on the everting installation process are discussed later within this disclosure. The everting liner 102 is configured to be installed in a borehole 104. A central tether 106 is attached to an end of the everting liner 102. When the system 100 is installed within the borehole 104, the tether 106 extends through the center of the liner 102 substantially the entire length of the liner 102. For example, the tether 106 can extend to within a few feet from a downhole end of an installed liner 102. The tether 106 is configured to retrieve the everting liner after installation. That is, the tether 106 is retracted during a retrieval process. Details on installation and removal of the system 100 are explained later within this disclosure. A cable 108 is configured to be installed into the borehole 104 with both the everting liner 102 and the central tether 106. In some implementations, the cable 108 is configured to detect acoustic waves within the borehole. For example, the cable 108 can include an optical fiber. In some implementations, the cable 108 runs substantially an entire length of the borehole 104 once installed. For example, the cable 108 can extend to within a few feet from a downhole end of an installed liner 102. In some implementations, the liner 102 can be filled with a fluid 114, such as water. Fluids

other than water can be used. For example, compressed gas can be used to press the liner against the wall while avoiding tube waves that can create noise in any signal received from the fiber. Additives, such as cement, sand, bentonite, or a combination, can be added to the fluid to improve coupling or attenuate acoustic signals as needed.

5 For example, when bentonite is added, bentonite swelling in the water provides a way to keep a stable suspension within the liner if additives are added.

[0043] In the illustrated implementation, the liner 102 is configured to be positioned between a wall of the borehole 104 and the cable 108 once installed. In some implementations, the cable 108 is attached to the liner 102. For example, the
10 cable 108 can be directly attached to the liner 102 with an adhesive. In some implementations, the liner 102 includes a pocket 110 that runs substantially an entire length of the liner 102. For example, the pocket 110 can extend to within a few feet from a downhole end of an installed liner 102. In such an implementation, the cable 108 runs through the pocket 110. The pocket can be formed from a strip of material
15 112 that is attached to the liner. In some implementations, the strip of material 112 can be made of the same material as the liner 102, or a different material than the liner 102. The strip of material 112 can be sewn to the liner 102, attached with adhesive, or attached by any other fasteners that does not compromise the structural integrity of the liner 102. For example, the strip of material 112 can include a strip of adhesive backed
20 tape.

[0044] FIG. 1B is a side cross-sectional view of the example system 100 as it is being installed into the borehole 104. As the liner 102 everts, a central part of the liner 102 passes through an outer part of the liner 102 until the central part of the liner rolls out to come in contact with the wall of the borehole. The tether 106 is pulled through
25 the center of the liner in a downhole direction 118 while the liner everts. In some implementations, a static or pressurized fluid can drive the everting motion. For example, compressed air or water can be used. In some implementations, the weight of the liner 102 itself can drive the everting motion.

[0045] FIG. 1C is a side cross-sectional view of the example system 100 after
30 being installed into the borehole 104. The installed system includes the tether 106 centrally positioned in the borehole 104. The tether attaches to a downhole end of the liner 102. The liner 102 is filled with a fluid 114. The fluid can be added during installation or after installation and includes properties tailored for the end user. In

some implementations, compressed gas or fluid can be used to provide just enough coupling necessary for acoustic recordings. Using compressed gas can also provide a way to uninstall the everting liner. The liner 102 is positioned between the cable 108 and the wall of the borehole 104. In some implementations, the cable 108 can include an optical fiber. In some implementations, the optical fiber can be a looped optical fiber that includes a turn-around assembly 116. Details of an example turn-around assembly are discussed later in this disclosure.

[0046] FIG. 2A shows a top-down view of an example of a liner and cable installed within a borehole. The system 200 includes an everting liner 202 configured to evert during installation. The everting liner 202 is configured to be installed in a borehole 204. A central tether 206 is attached to an end of the everting liner 202. When the system 200 is installed within the borehole 204, the tether 206 extends through the center of the liner 202 substantially the entire length of the liner 202. For example, the tether 206 can extend to within a few feet from a downhole end of an installed liner 202. The tether 206 is configured to optionally retrieve the everting liner 202 after installation. That is, the tether 206 is retracted during a retrieval process. A cable 208 is configured to be installed into the borehole 204 with both the everting liner 202 and the central tether 206. In some implementations, the cable 208 is configured to detect acoustic waves within the borehole. For example, the cable 208 can include an optical fiber. In some implementations, the cable 208 runs substantially an entire length of the borehole 204 once installed. For example, the cable 208 can extend to within a few feet from a downhole end of an installed liner 202. In some implementations, the liner can be filled with a fluid 214, such as water. Fluids other than water can be used. For example, compressed gas can be used to press the liner against the wall while avoiding tube waves that can create noise in any signal received from the fiber. Additives, such as cement, sand, bentonite, or a combination, can be added to the fluid to improve coupling or attenuate acoustic signals as needed. In some implementations, these additives can assist in making the everted liner a permanent installation.

[0047] In the illustrated implementation, the cable 208 is configured to be positioned between a wall of the borehole 204 and the liner 202 once installed. In some implementations, the cable 208 is attached to the liner 202. For example, the

cable 208 can be directly attached to the liner 202 with an adhesive, tape, or any other fastener.

[0048] FIG. 2B is a side cross-sectional view of the example system 200 as it is being installed into the borehole 204. As the liner 202 everts, a central part of the liner 202 passes through an outer part of the liner 202 until the central part of the liner rolls out to come in contact with the wall of the borehole. The tether 206 is pulled through the center of the liner in a downhole direction 218 while the liner everts. In some implementations, a static or pressurized fluid can drive the everting motion. For example, compressed air or water can be used. In some implementations, the weight of the liner 202 itself can drive the everting motion.

[0049] FIG. 2C is a side cross-sectional view of the example system 200 after being installed into the borehole 204. The installed system includes the tether 206 centrally positioned in the borehole 204. The tether attaches to a downhole end of the liner 202. The liner 202 is filled with a fluid 214. The fluid can be added during installation or after installation and includes properties tailored for the end user. In some implementations, compressed gas or fluid can be used to provide sufficient coupling necessary for acoustic recordings. Using compressed gas can also provide a way to uninstall the everting liner. The cable 208 is positioned between the liner 202 and the wall of the borehole 204. In some implementations, the cable can include an optical fiber. In some implementations, the optical fiber can be a looped optical fiber that includes a turn-around assembly 216. Details of an example turn-around assembly are discussed later in this disclosure. In some implementations, the optical fiber can be terminated at the assembly 216. This assembly, when terminated, may include an additional sensor which uses the optical fiber for telemetry. This sensor may include electromagnetic sensors, acoustic sensors, or gyroscopic sensors to determine the fiber position and depth in the borehole during the installation process when the liner is everting into the borehole.

[0050] FIG. 3A shows a top-down view of an example of a liner and cable installed within a borehole. The system 300 includes an everting liner 302 configured to evert during installation. The everting liner 302 is configured to be installed in a borehole 304. A central tether 306 is attached to an end of the everting liner 302. When the system 300 is installed within the borehole 304, the tether extends through the center of the liner 302 substantially the entire length of the liner 302. For example,

the tether 306 can extend to within a few feet from a downhole end of an installed liner 302. The tether 306 is configured to retrieve the everting liner after installation. That is, the tether 306 is retracted during a retrieval process. A cable 308 is configured to be installed into the borehole 304 with both the everting liner 302 and the central tether 306. In some implementations, the cable 308 is configured to detect acoustic waves within the borehole. For example, the cable 308 can include an optical fiber. In some implementations, the cable 308 runs substantially an entire length of the borehole 304 once installed. In some implementations, the liner can be filled with a fluid 314, such as water or any other fluid dense enough to provide adequate acoustic coupling with the formation. Additives, such as cement, sand, bentonite, or a combination can be added to the fluid to improve coupling or attenuate acoustic signals as needed.

[0051] In the illustrated implementation, the cable 308 is attached to the tether 306. The cable 308 can be directly attached to the tether 306 with an adhesive, zip ties, clamps, or any other attachment mechanism. Alternatively or in addition, stronger fiber cable itself can be used as a tether, provided it has surrounding providing enough strength, although fiber under tension may be subject to parasitic string modes.

[0052] FIG. 3B is a side cross-sectional view of the example system 300 after being installed into the borehole 304. As the liner 302 everts, a central part of the liner 302 passes through an outer part of the liner 302 until the central part of the liner rolls out to come in contact with the wall of the borehole. The tether 306 is pulled through the center of the liner in a downhole direction 318 while the liner everts. In some implementations, a static or pressurized fluid can drive the everting motion. For example, compressed air or water can be used. In some implementations, the weight of the liner 302 itself can drive the everting motion.

[0053] The installed system includes the tether 306 centrally positioned in the borehole 304. The tether attaches to a downhole end of the liner 302. The liner 302 is filled with a fluid 314. The fluid 314 can be added during installation or after installation and includes properties tailored for the end user. The cable 308 is attached to the tether 306. In some implementations, the cable 308 can include an optical fiber. In some implementations, the optical fiber can be a looped optical fiber that includes a turn-around assembly 316. Details of an example turn-around assembly are discussed later in this disclosure.

[0054] FIG. 4 is a side cross-sectional view of an example turn-around assembly 400 that can be used with aspects of this disclosure. The turn-around assembly 400 can be used for any of the previously described turn-around assemblies. The turn-around assembly 400 includes a glass cap 402 where conventional fiber is spliced (in a controlled way during manufacturing to minimize optical losses) to another special fiber 408 that can bend at a much tighter radius with smaller optical loss. The glass cap 402 can be made of glass, ceramic, stiff elastomers, metal, or any other material that is suitable for the borehole environment. The glass cap 402 defines a space sufficient for a minimum bend radius of a looped fiber cable 408. In some instances, the minimum bend radius of a fiber cable can be rather small, allowing turnaround assembly to be 2.2 millimeters (mm) or less in diameter. Such small size is allows efficient installation in the boreholes. The looped fiber cable 408 can be used for any of the previously described cables. The glass cap 402 is configured to protect the fiber.

[0055] FIG. 5 is a flowchart of an example method 500 performed by an everting liner that can be used with aspects of this disclosure. At 502, a borehole is traversed by the everting liner from an upper end of the borehole to substantially a lower end of the borehole. For example, the liner can traverse to within a few feet of the bottom of the borehole. At 504, a cable attached to the everting liner is carried into the borehole by the everting liner. At 506, a tether attached to the everting liner is carried into the borehole. The tether is attached to an end of the everting liner that is configured to be at the downhole end of the borehole after traversing the borehole. In some implementations, an acoustic coupling medium is received into the everted liner. The acoustic coupling medium can include cement, sand, bentonite, water, or any other appropriate medium. In some instances, the cable includes an optical fiber. In some instances, the optical fiber can be deformed by an acoustic wave passing through the optical fiber.

[0056] In some instances, the everting liner system is a temporary installation. In such an instance, the everting liner can traverse out of the borehole carrying the cable out with the everting liner. In some instances, the everting liner system is a permanent installation. In such an instance, a cement cap is received at an up-upper end of the liner. This procedure can be used on boreholes 2 inches in diameter or less

(microholes) up to larger boreholes of 20 inches or more in diameter. Deviated and horizontal wells can also be serviced in a similar manner.

[0057] While this disclosure contains many specific implementation details, these should not be construed as limitations on the scope of what may be claimed, but rather as descriptions of features specific to particular implementations. Certain features that are described in this disclosure in the context of separate implementations can also be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation can also be implemented in multiple implementations separately or in any suitable subcombination. Moreover, although features have been described as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a subcombination or variation of a subcombination.

[0058] Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. Moreover, the separation of various system components in the implementations previously described should not be understood as requiring such separation in all implementations, and it should be understood that the described components and systems can generally be integrated together in a single product or packaged into multiple products.

[0059] Thus, particular implementations of the subject matter have been described. Other implementations are within the scope of the following claims. In some cases, the actions recited in the claims can be performed in a different order and still achieve desirable results. In addition, the processes depicted in the accompanying figures do not necessarily require the particular order shown, or sequential order, to achieve desirable results. What is claimed is:

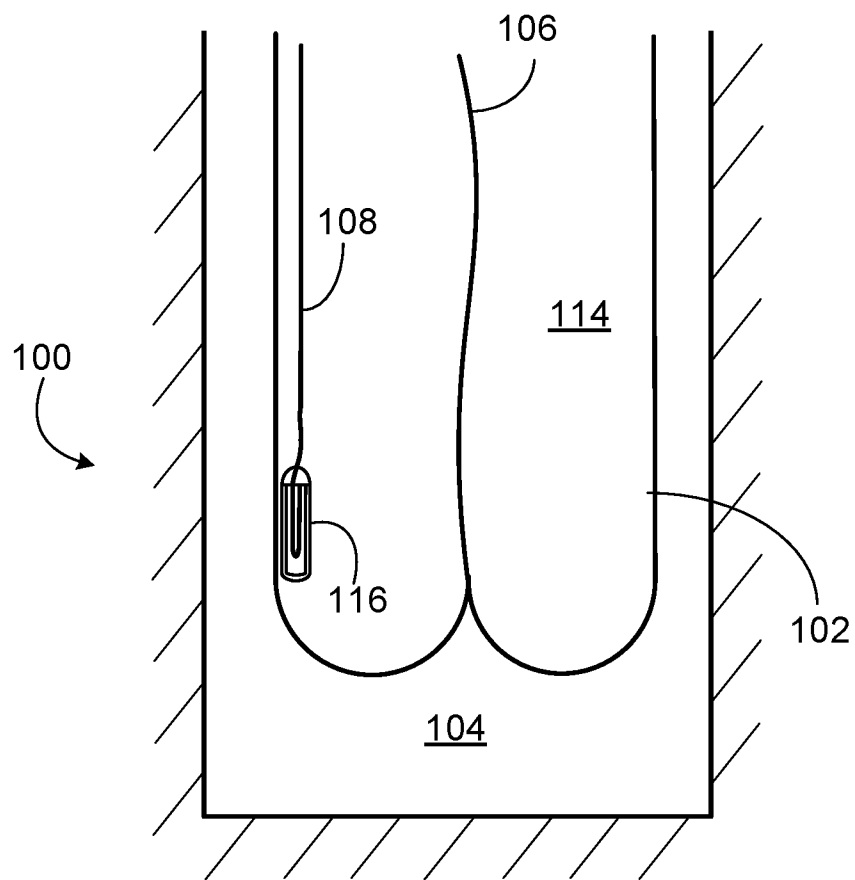
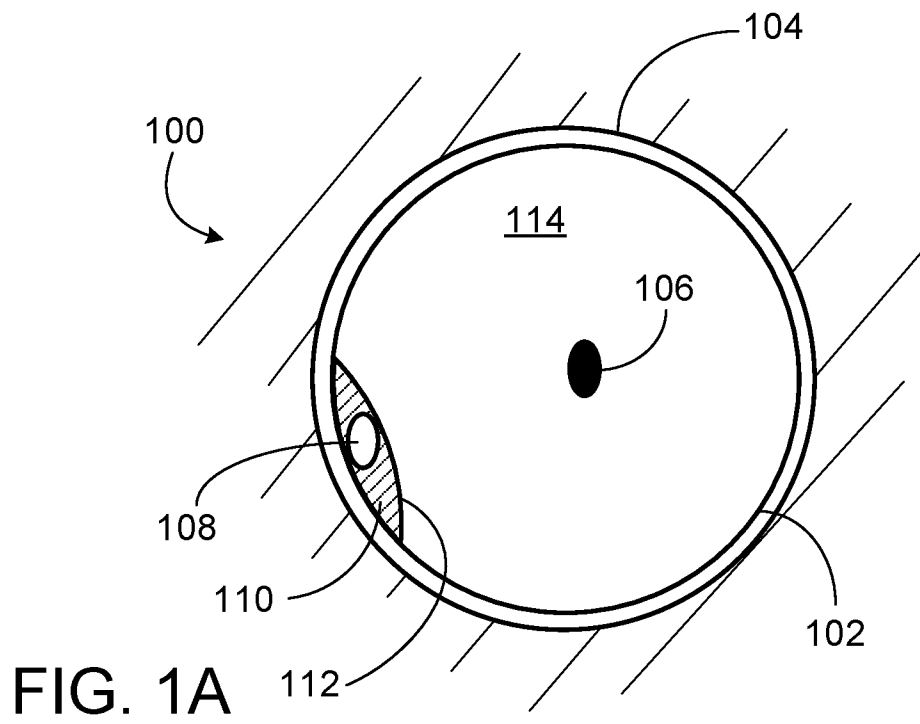
CLAIMS

1. A method performed by an everting liner, the method comprising:
 - traversing through a borehole from an upper end of the borehole to substantially a lower end of the borehole;
 - 5 carrying a cable attached to the everting liner into the borehole; and
 - carrying a tether attached to the everting liner into the borehole, the tether attached to an end of the everting liner that is configured to be at the downhole end of the borehole after traversing the borehole.
- 10 2. The method of claim 1, further comprising:
 - receiving an acoustic coupling medium into the everted liner.
3. The method of claim 2, wherein the acoustic coupling medium comprises cement, sand, bentonite, or water.
- 15 4. The method of claim 1, further comprising deforming the cable by an acoustic wave passing through the cable.
5. The method of claim 1, further comprising:
 - 20 traversing out of the borehole; and
 - carrying a cable out of the borehole.
6. The method of claim 1, further comprising receiving a cement cap at an upper end of the liner.
- 25 7. A system comprising:
 - an everting liner configured to evert during installation, the everting liner configured to be installed in a borehole;
 - a central tether attached to an end of the everting liner, the tether
 - 30 configured to retrieve the everting liner after installation, the tether configured to travel through the everting liner during installation; and
 - a cable configured to be installed into the borehole with both the everting liner and the central tether, the cable configured to detect acoustic waves within the borehole.

8. The system of claim 7, wherein the cable comprises an optical fiber.
9. The system of claim 8, wherein the optical fiber comprises a looped fiber cable,
5 the looped fiber cable comprising a turn-around assembly.
10. The system of claim 9, wherein the turn-around assembly comprises a glass cap
defining a space sufficient for a minimum bend radius of the looped fiber
cable, the glass cap configured to protect the fiber.
- 10 11. The system of claim 7, wherein the cable is attached to the tether.
12. The system of claim 7, wherein the cable is attached to the liner.
- 15 13. The system of claim 12, wherein the cable is configured to be between a wall
of a borehole and the everted liner once installed.
14. The system of claim 12, wherein the liner is configured to be between a wall of
a borehole and the cable once installed.
- 20 15. The system of claim 12, wherein the cable is directly attached to the liner with
an adhesive.
16. The system of claim 12, wherein the liner comprises a pocket that runs
25 substantially an entire length of the liner, the cable running through the pocket.
17. The system of claim 7, wherein the cable runs substantially an entire length of
the borehole.
- 30 18. A system comprising:
an everting liner configured to evert during installation, the everting
liner configured to be installed in a borehole;
a central tether attached to an end of the everting liner, the tether
configured to retrieve the everting liner after installation, the tether configured
35 to travel through the everting liner during installation; and
an optical fiber that is attached to and runs a length of the everting liner,
the optical fiber configured to be installed into the borehole with both the

everting liner and the central tether, the cable being configured to be between a wall of a borehole and the everted liner once installed, the cable configured to detect acoustic waves within the borehole.

- 5 19. The system of claim 18, wherein the optical fiber comprises a looped fiber cable, the looped fiber cable comprising a turn-around assembly.
20. The system of claim 19, wherein the turn-around assembly comprises a glass cap defining a space sufficient for a minimum bend radius of the looped fiber
- 10 cable, the glass cap configured to protect the fiber.



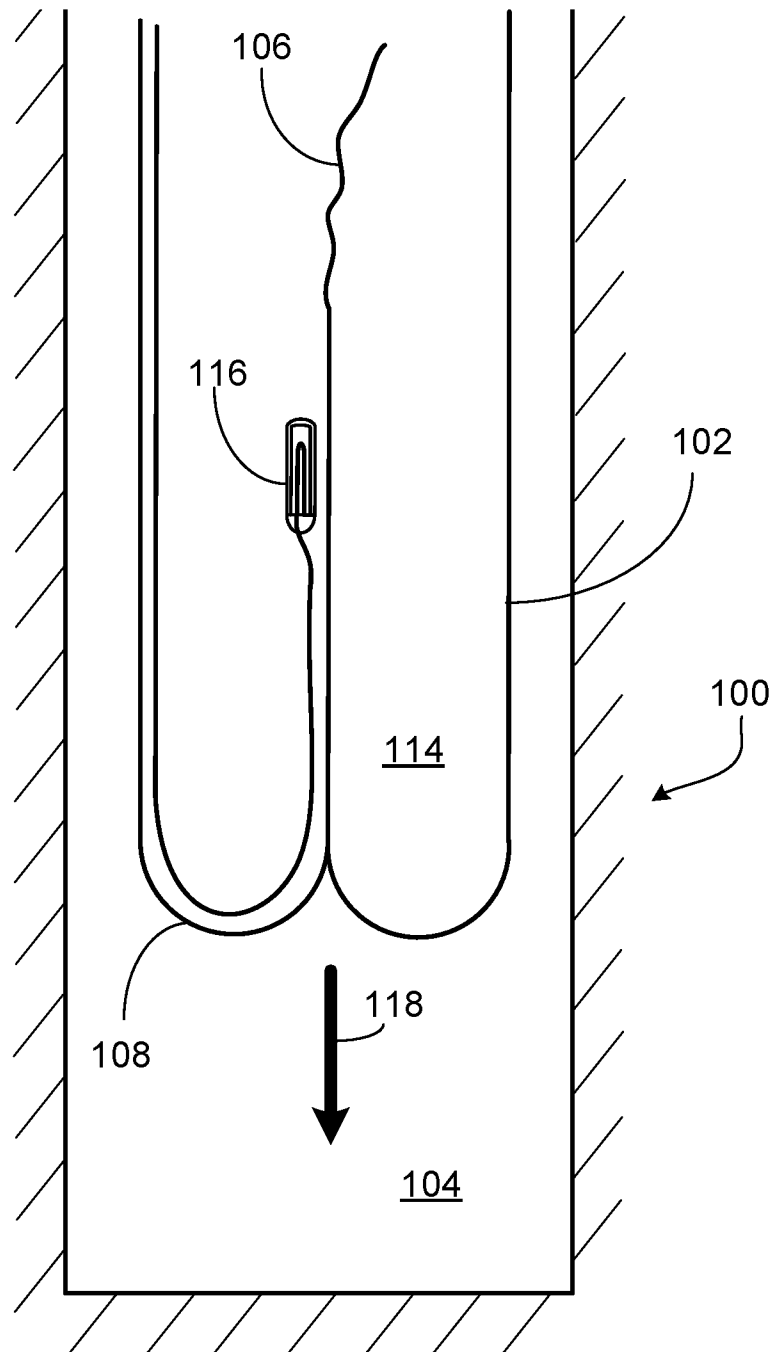
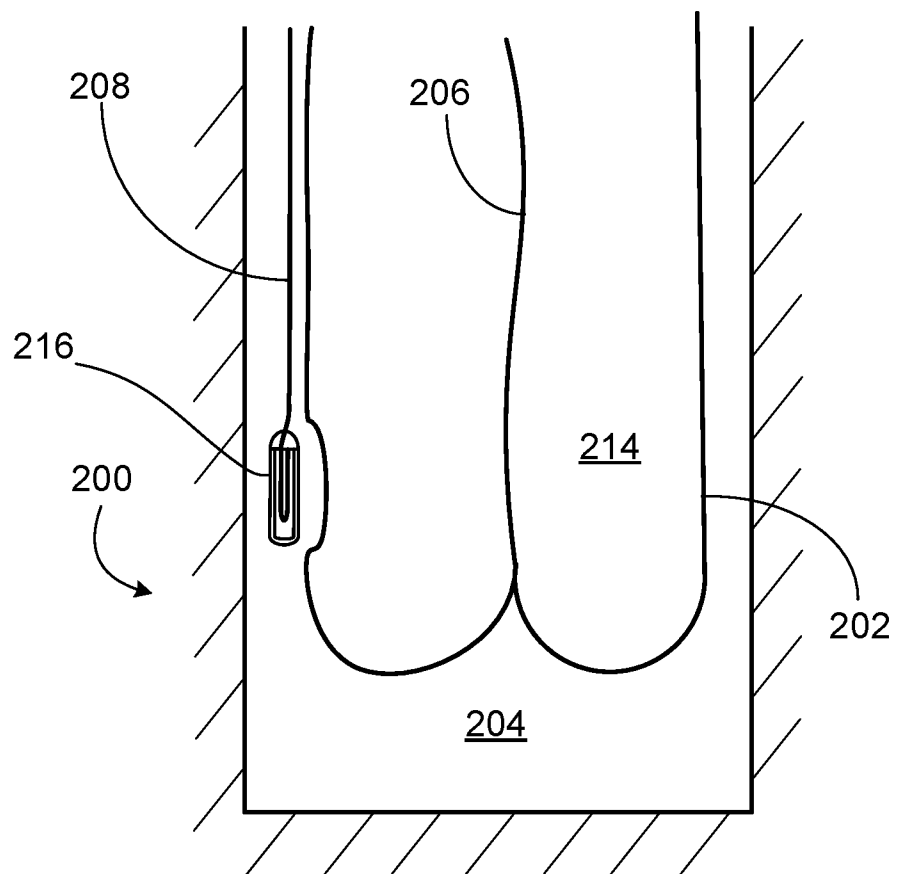
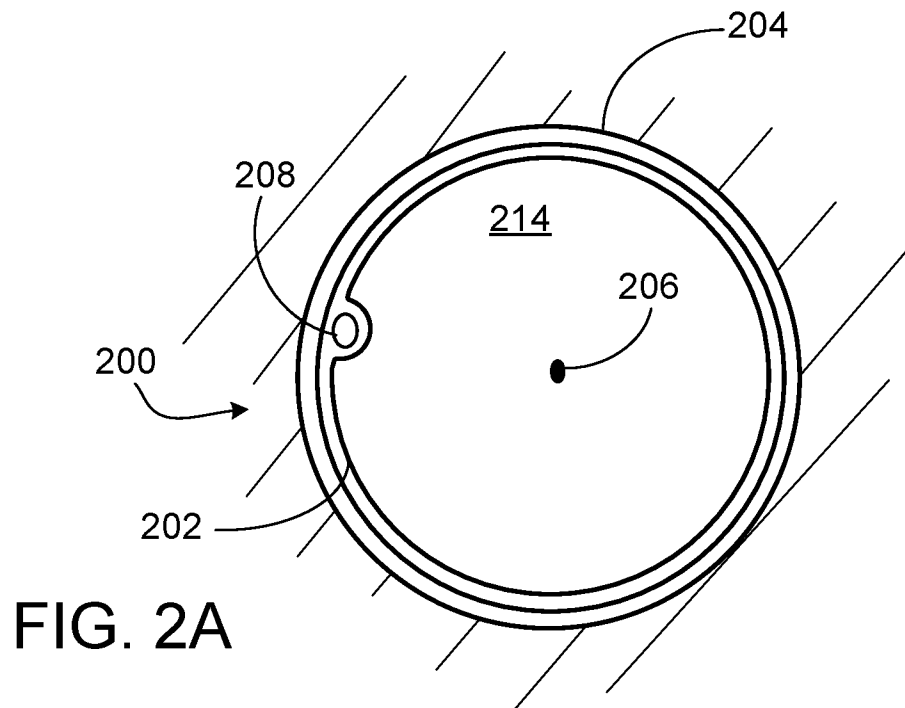


FIG. 1B



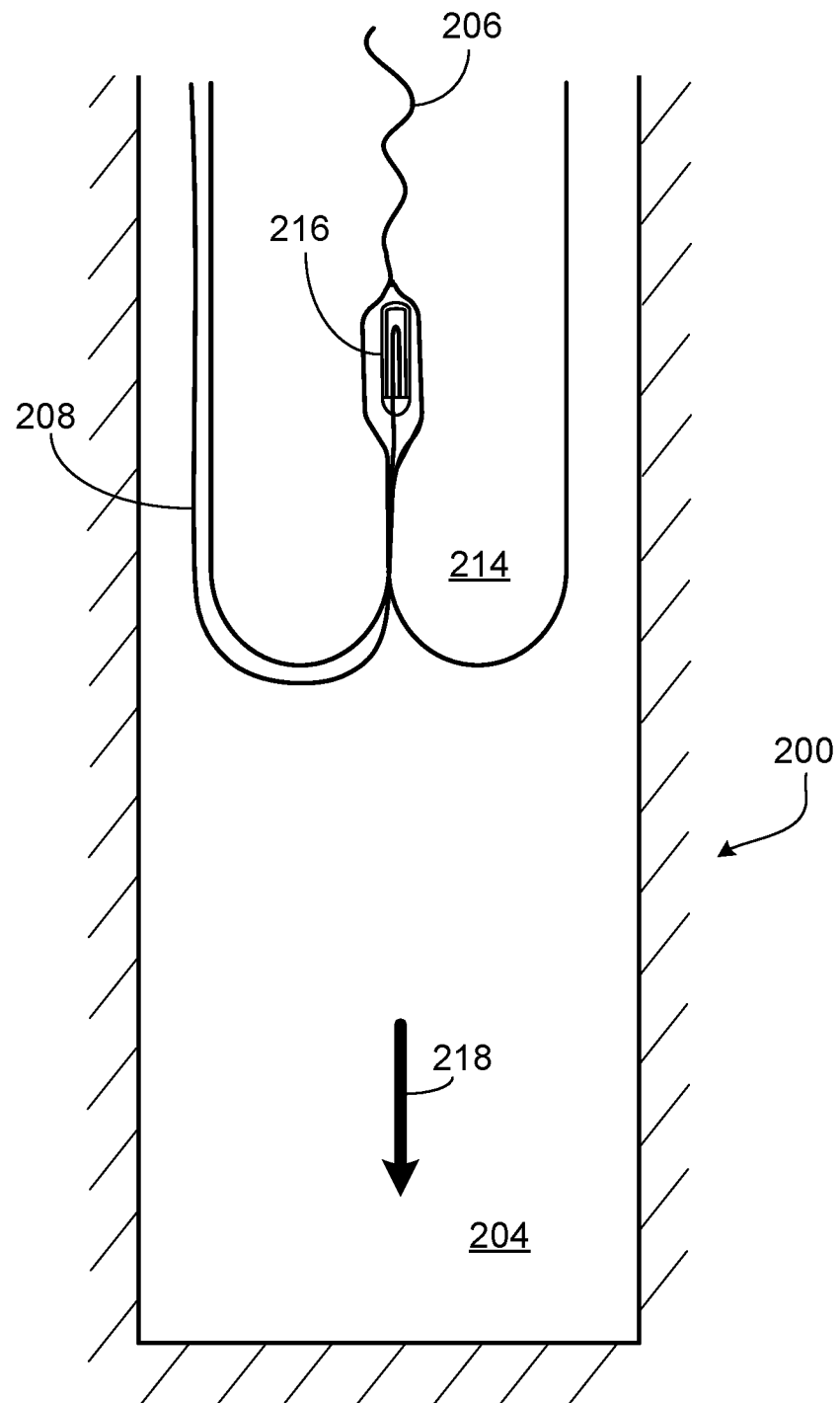
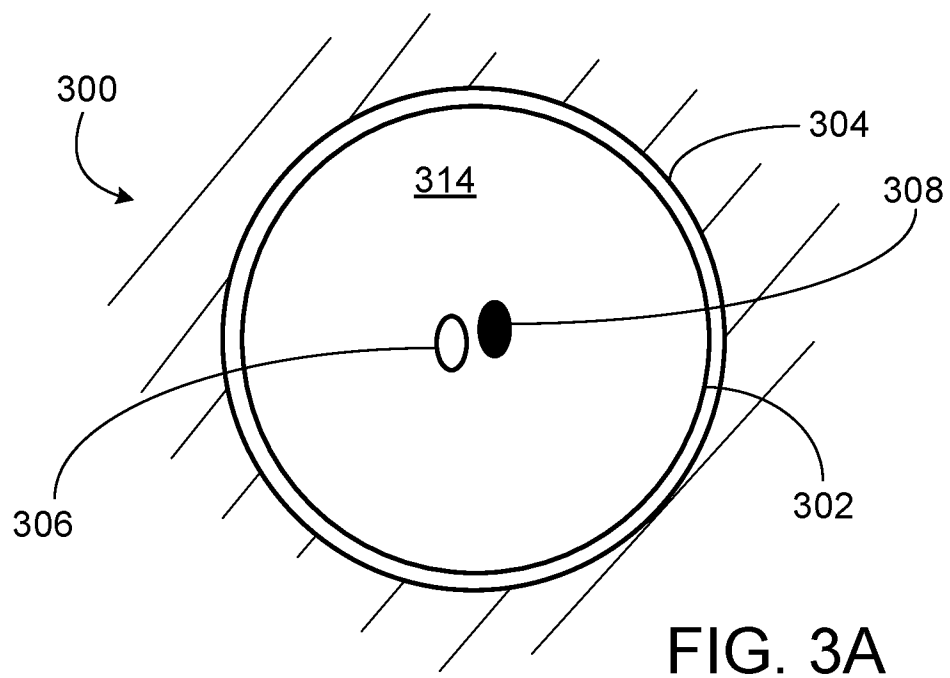
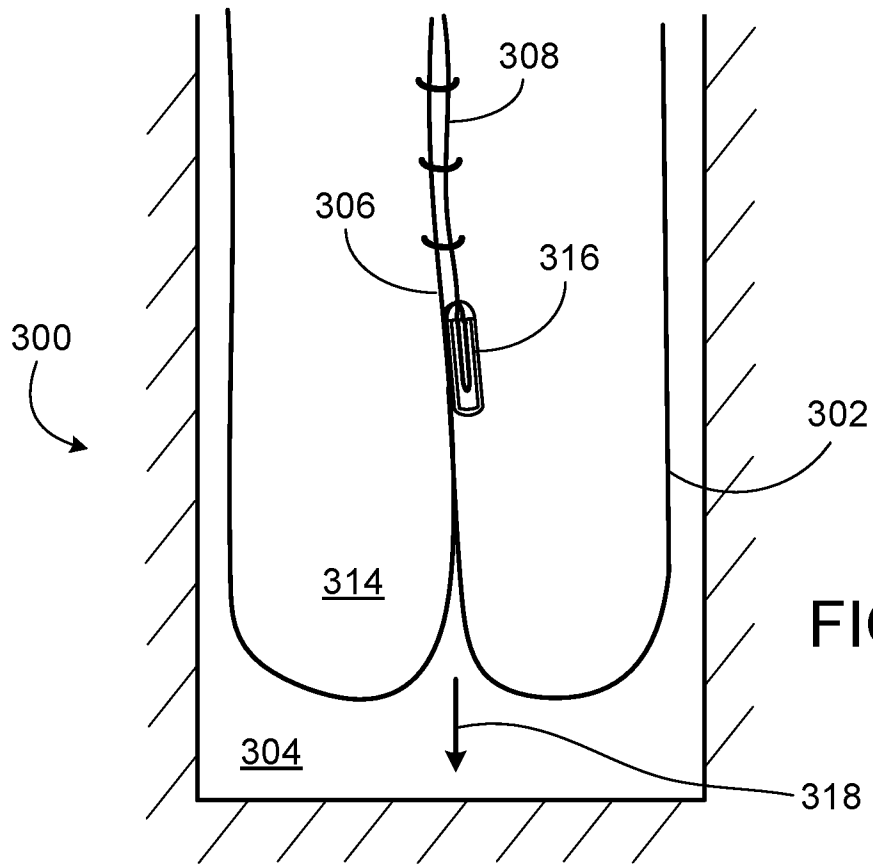


FIG. 2B



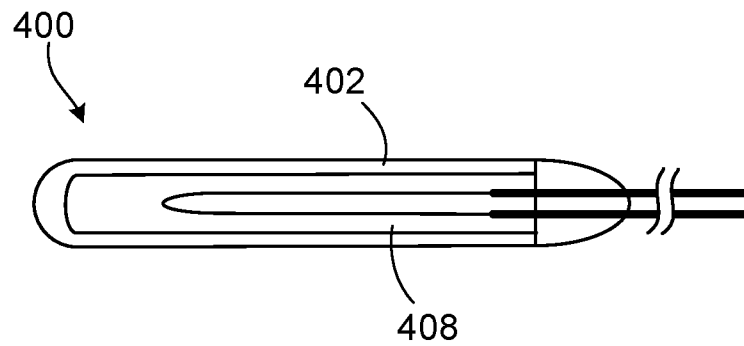


FIG. 4

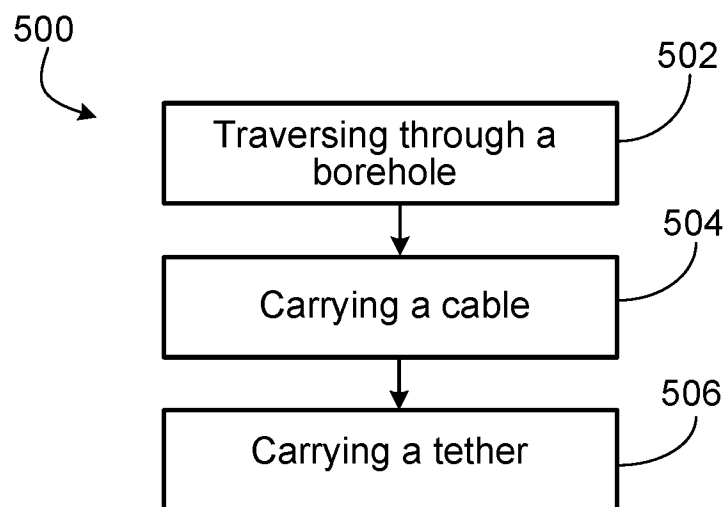


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/039806

A. CLASSIFICATION OF SUBJECT MATTER

INV. E21B43/10 E21B47/01 E21B47/10 G02B6/50 G02B6/44
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B F16L G02B H02G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 176 207 A (KELLER CARL E [US]) 5 January 1993 (1993-01-05)	1-8,12, 13,15, 17,18
Y	column 2, lines 15-45 column 3, line 4 - column 4, line 11 column 4, lines 47-60; figures 1-3 -----	9-11,14, 16,19,20
Y	US 2010/200248 A1 (KRIESEL PETRUS CORNELIS [NL] ET AL) 12 August 2010 (2010-08-12)	11,14,16
A	paragraphs [0009] - [0012], [0039] - [0053]; figures 4-9 -----	1,7,18
Y	US 2006/104578 A1 (HERBST BRIAN G [US]) 18 May 2006 (2006-05-18) paragraphs [0003], [0024], [0025]; figure 1 ----- -/--	9,10,19, 20



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

12 September 2019

Date of mailing of the international search report

24/09/2019

Name and mailing address of the ISA/

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Authorized officer

Jucker, Chava

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/039806

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MUNN JONATHAN D ET AL: "Novel cable coupling technique for improved shallow distributed acoustic sensor VSPs", JOURNAL OF APPLIED GEOPHYSICS, ELSEVIER, AMSTERDAM, NL, vol. 138, 7 January 2017 (2017-01-07), pages 72-79, XP029939210, ISSN: 0926-9851, DOI: 10.1016/J.JAPPGEO.2017.01.007 abstract Chapter 2.3 "Field depoyment", Fig. 2 -----	7,8,13, 17
A	US 2001/017163 A1 (PENZA G GREGORY [US]) 30 August 2001 (2001-08-30) paragraphs [0002], [0026] - [0028]; figures 12-14 -----	1,7,16, 18

INTERNATIONAL SEARCH REPORT

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