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(54) Title: SMART PORTABLE NON-ROTATING PROTECTOR COMPOSITE EMBEDDED DISTRIBUTED SENSING

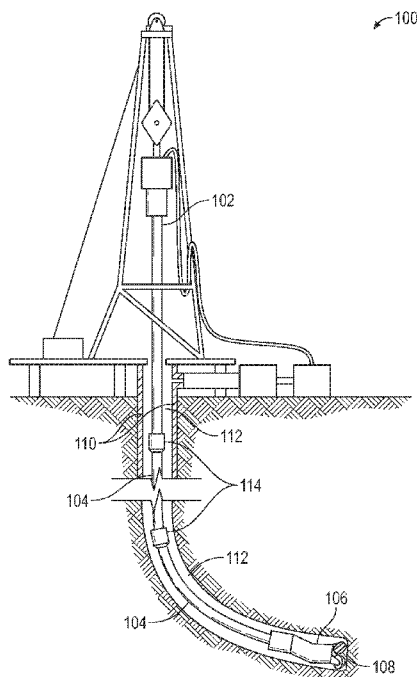


FIG. 1

(57) Abstract: An apparatus for measuring environmental parameters along a drill string includes a protector disposed radially around the drill string, and a sensor system with an optical fiber configured to collect data on environmental conditions within a wellbore through which the drill string is being inserted. Protector is made of a composite material having the sensor system and the optical fiber embedded within. Collected data may be extracted from the sensor system. A method of collecting data on environmental conditions within a wellbore includes disposing a sensor system onto a matrix substrate of a protector; coating the sensor system and matrix substrate with a composite material; curing the composite material so as to embed the sensor system within the protector; forming a protector around a drill string; using the sensor system to collect data from within the wellbore upon insertion of the drill string and protector; and retrieving the collected data.

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SMART PORTABLE NON-ROTATING PROTECTOR COMPOSITE EMBEDDED DISTRIBUTED SENSING

BACKGROUND OF INVENTION

[0001] Oil or gas wells are drilled using a drill string. The drill string includes the drill pipe, drill bit, drill collars, and any other down-hole components used to make the drill bit turn at the bottom of the wellbore and take measurements about the drill string and wellbore environment. As can be seen in Figure 1, the rig 100 sits at the surface of the well and drives the drill string 102. The drill pipe 104 extends to the bottom hole assembly 106, which includes the drill bit 108 that ultimately drills the well.

[0002] After predetermined length of the well is drilled, a section of casing 110 is inserted into the wellbore. Casing 110 provides zonal isolation, and also provides a number of other functions such as preventing the wellbore 112 from caving in, preventing fluids used during the drilling process from contaminating the surrounding formations, pressure control, etc. The casing 110 is then cemented and, when cement is set, another section of the wellbore 112 is drilled. During this process, the drill string 102, at times, is exposed to high torque and stress at parts of the casing, cementing, and the wellbore 112.

[0003] More specifically, during the rotary drilling operations, whenever the drill pipe 104 comes in contact with the casing 110 or the wall of the wellbore 112, it is subject to abrasion and shock. In case of deviated well drilling, the drill pipe 104 is exposed to a curved path. During these instances, the effects of frictional forces developed between the rotating drill pipe and the casing 110 or the wall of the well bore 112 are increased and a considerable amount of torque is required.

[0004] In view of the above, the drill pipe 104 has one or more protectors 114 installed at various points thereon. The one or more protectors 114 may be placed at several location along the length of the drill pipe in order to reduce torque and friction. In order to do so, the one or more protectors 114, keep the drill pipe 104, and any down-hole components connected thereto, isolated from the wall of the casing 110 and wellbore 112. Thus, energy transfer to the bit is optimized and drill string

drag, required input torque, casing and riser wear, buckling, and heat is reduced. The protectors 114 may be non-rotating protectors, i.e., the protectors 114 are assembled in a separated manner around the drill pipe 104 such that the drill pipe 104 rotates within the protectors 114, while the protectors themselves do not rotate.

[0005] Figure 2 shows a protector sleeve 114 installed on a drill 104 pipe between an upper thrust collar 101 and lower thrust collar 103 near a tool joint 105. The protector sleeve 114 may include flutes to improve flow and have a slightly larger outer diameter than the tool joint 105 in order to create standoff between the tool joint 105 and the casing 110. Protector sleeves 114 are typically made of composites, low coefficient friction rubber, or polymeric materials so as to reduce drag. The drill pipe 104 may be connected with hundreds of these protectors 114 in the wellbore. These protectors 114 at different points can generate sufficient accumulative torque or drag to adversely affect the casing, cementing, and formations.

SUMMARY OF INVENTION

[0006] In accordance with one or more embodiments, the present invention relates to an apparatus for measuring environmental parameters along a drill string, the system comprising: a protector disposed radially around the drill string, and a sensor system with an optical fiber configured to collect data on environmental conditions within a wellbore through which the drill string is being inserted, wherein the protector is made of a composite material having the sensor system and the optical fiber embedded within, and wherein the collected data is capable of being extracted from the sensor system.

[0007] In accordance with one or more embodiments, the present invention relates to a method of collecting data on environmental conditions within a wellbore, the method comprising: disposing a sensor system onto a matrix substrate of a protector; coating the sensor system and matrix substrate with a composite material; curing the composite material so as to embed the sensor system within the protector; forming a protector around a drill string to be inserted into the wellbore; using the sensor system to collect data from within the wellbore upon insertion of the drill string and protector; and retrieving the collected data for processing.

[0008] Other aspects and advantages of the invention will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

[0009] Figure 1 shows an installation system of non-rotating drill pipe protector.

[0010] Figure 2 shows a drill pipe string and non-rotating drill pipe protectors.

[0011] Figure 3 is a schematic of a composite material protector having a sensor system with optical fibers embedded therein in accordance with one or more embodiments of the invention.

[0012] Figure 4 is a schematic of a composite material protector having a sensor system with optical fibers embedded therein in accordance with one or more embodiments of the invention.

[0013] Figure 5 shows details of the sensor system and optical fibers are shown in accordance with one or more embodiments of the invention.

[0014] Figure 6 shows a method in accordance with one or more embodiments of the invention.

DETAILED DESCRIPTION

[0015] Drill pipe and casing protectors are typically made of composite materials, low coefficient friction rubber, or polymeric materials. An advantage of this fact is that fiber optics and acoustic sensors may be embedded into the protectors during manufacture. As modern design moves more towards the use of lighter and stronger composite materials, it must also move towards smarter materials. Doing so will reduce the requirement for frequent inspection and monitoring of conditions within a wellbore.

[0016] Embodiments of the present invention relate to drill pipe and casing protectors having embedded sensors, and a method to embed such sensors within the protectors, as well as collect the process data from the embedded sensors. More particularly, embodiments involve the use of fiber optics and sensors to sense and collect data (such as strain and temperature), and communicating the data using miniaturized

distributed optical fiber sensing coupled to the protectors. The data collected during the drilling process allows validation of the wellbore and casing/cementing integrity during drilling operations. That is, an embedded, distributed optical fiber sensing technique is used to measure strain and temperature, with the goal of monitoring the status for casing and wellbore integrity. Because strain and temperature are inductive of damage to the casing/cementing or wellbore during drilling operations detection and measurement of these conditions can be used to identify stressed areas that may impact well production in the future.

[0017] Photonics offers an elegant solution to this problem in the form of embedded fiber optic sensors. The fiber optics, sensors, and electronics can be directly embedded into the composite material, forming an ideal material and sensor combination. There are many considerations to successfully integrating fiber sensors into composite materials. Issues include the manufacturing process to integrate the sensors without compromising the composite material, sensor ingress/egress, and the like. In addition, an acoustic sensing method has been used through the industry to measure sound levels and frequency for many applications. Such acoustic sensors can be embedded into the composite structure of a protector so as to detect the quality of cement bonding behind the casing based on sound and frequency. Miniaturized versions of these sensor devices allow the entirety of the sensor system to be embedded in non-metallic protectors and be deployed in portable configuration.

[0018] Referring to Figure 3, a schematic of a composite material protector 300 having a sensor system 302 with optical fibers 304 embedded therein in accordance with one or more embodiments of the invention. Those skilled in the art will appreciate that, while the material is shown flat for purposes of illustration, the protector may be manufactured either as a flat article that is later processed to obtain a tubular shape or may be manufactured in a tubular shape directly. Regardless of the method of manufacture of the protector, the sensor system and optical fibers will be embedded in the same manner.

[0019] The protector assembly includes a low friction advanced polymer (plastic, rubber) sleeve and two aluminum collar clamps. Plastic polymer on the outside, rubber on the inside, molded around a metal cage. Different materials for both the

interior and exterior of the sleeve can be utilized based on downhole temperature and pressure requirements.

[0020] Typically, the matrix is made from thermoplastic materials such as Polyphenylene Sulfide (PPS) or Polyurethane. Polyphenylene sulfide (PPS) is a semicrystalline material. It offers an excellent balance of properties, including high temperature resistance, chemical resistance, flowability, dimensional stability and electrical characteristics. Polyurethane (PU) is a composite material made of: (1) one or more layers of polymer resins joined by urethane links; and (2) a woven or non-woven textile backing such as polyester, cotton, nylon, or ground leather. Typically, nitrile rubber or hydrogenated nitrile butadiene rubber can be used inside the sleeve. Nitrile rubber, also known as NBR, Buna-N, and acrylonitrile butadiene rubber, is a synthetic rubber copolymer of acrylonitrile (ACN) and butadiene. Hydrogenated nitrile butadiene rubber (HNBR), also known as highly saturated nitrile (HSN), is widely known for its physical strength and retention of properties after long-term exposure to heat, oil and chemicals. Under certain circumstances, reinforcement may or may not be required. However, if reinforcement is required, typically, a chopped reinforcement (e.g., glass, carbon, or the like) is mixed with the matrix in order to improve the mechanical strength of the protector.

[0021] The optical fiber sensor system is embedded within the protector whether at the matrix or between matrix and rubber. This embedding can be done during the molding process. The main driver of using non-metallic materials is the optical fiber sensor system can be embedded, while that would not be possible with metallic materials. The optical fiber sensor system is well protected by plastic materials and fiber optics termination design is able to collect more data during drilling operation. In addition to sensor system and optical fibers, reference point measurements such as temperature sensors (e.g., thermocouples) and acoustic sensors (e.g., microphones) can also be integrated and embedded into the protector.

[0022] Referring to Figure 4, in one or more embodiments, additional process steps can be taken to enhance the temperature and strain measurement. The elements of the system are the same as those shown in Figure 3, i.e., sensor system 302 and optical fibers 304 are embedded in protector 300. However, in these embodiments, a method

is used that improves temperature and strain resolution by increasing the Rayleigh scattering in the optical fibers.

[0023] The increase in Rayleigh scattering is achieved by exposing specific areas of the optical fiber core with ultra violet light. By doing so, high density of scattering defects are created on predetermined boundaries that maps to the length of the non-rotating protector segments, as shown in Figure 4. These segments are aligned with the non-rotating composite protector segments that will be in contact with the casing/cementing or wellbore surface. A solid-state argon laser can be used without any critical alignment to create the high density defects.

[0024] Referring to Figure 5, the details of the sensor system and optical fibers are shown. As with other embodiments, the composite material protector 300 has a sensor system 302 with optical fibers 304 embedded therein. As can be seen in the detailed view, sensor system 302 comprises a laser 500, a 90/10 beam splitter, 502, a circulator 504, a delay optical fiber 506, a 50/50 beam splitter 508, a photodetector 510, an analog-to-digital (A/D) converter 512, a Fast Fourier Transform (FFT) component 514, and a digital storage / Data Acquisition (DAQ) component 416. The DAQ 516 comprises processors and memory programmed to collect sensor data and store the collected data in the digital storage. Also, DAQ 516 is connected to an input/output (I/O) interface 518 which allows the stored data to be extracted from the sensor system 302 and for additional elements, such as one or more thermosensors 520 (e.g., thermocouple), one or more acoustic sensors 522 (e.g., microphone), and/or one or more power sources 524 (e.g., rechargeable batteries), to be connected to the sensor system 302. Alternatively, in one or more embodiments, these elements may be directly integrated into the embedded sensor system 302.

[0025] One or more embodiments may use a classical fiber optic measurement system, such as distributed acoustic sensing (DAS) system and/or optical frequency domain reflectometry (OFDR). The reflectivity pattern that is measured using OFDR along the optical fiber length. The defects in the optical fiber induces a local vibration in the permittivity which results in Rayleigh back scatter. The knowledge of the spectral intensity of an inference between the fiber for sensors and reference arm provides the measurement of the permittivity variation. The measurement of temperature and strain is relative to reference measurement. For both measurements,

comparison is made by doing cross-correlation over an integration length. This cross-correlation is in the frequency domain. In cases where there is no strain or temperature change, there is a peak at zero frequency. When there is an applied change in this parameters, the change in the frequency shift is proportional to the change.

[0026] Each embedded sensor system 302 has digital ID, which is used to correlate its motion and position of the protector with reference to the drill string. The protector devices can be positioned randomly or to designated positions where needed. The specific position could be correlated with specific zones, curves, etc. Once the drill string is removed, the data measured and stored in the device can be retrieved and further processing and analysis of data is performed.

[0027] In one or more embodiments, the components of the sensor system can be located at the surface in an interrogation box. That is, in one or more embodiments, all optical arrangements within the sensor system 302 as shown in Figure 5 are located at the surface to provide the interrogating light beam (laser light from laser 500) and receive the scattered beam on the same fiber 304 to measure both temperature and acoustic signatures from the end of the fiber.

[0028] Referring to Figure 6, a method in accordance with one or more embodiments is shown. First, the sensor system is disposed onto the matrix substrate of the protector in step 600. Then, the sensor system and matrix substrate of the protector is coated with composite material in step 602 and the composite material is cured so as to embed the sensor system into the protector in step 604. The protector with the embedded sensor system is formed from the cured material and installed onto a drill string in step 606. Once the protector with the embedded sensor system is inserted downhole, data from the downhole environment is collected by the sensor system in step 608. Finally, once the protector with the embedded sensor system is removed from downhole, the collected data may be retrieved and processed in step 610. Those skilled in the art will appreciate that, in one or more embodiments having different configurations, certain steps may be performed in a different orders and/or other steps may be performed or not performed based on the configuration of the sensor system being employed.

[0029] One or more embodiments of the present invention may include one or more of the following advantages. The sensor device and optical fiber is embedded in a protector and enabled as individual portable device. By using special optical fibers for sensing, the sensing is immune to interference. More specifically, the use of optical fibers as sensors, in particular special optical fibers that is designed to have higher Rayleigh scattering, which is the techniques use for the measurement here, and it is immune to electrical interference. By embedding optical, acoustic, and piezoelectric sensors in composite drill pipe protectors, which allows the integral sensors to make several measurements, embodiments are advanced as compared to conventional parts.

[0030] The fiber itself is not affected by the environment due to being embedded in the drill string. However, the signal received from the optical fiber is subject to the environment changes and this is what is needed for the temperature and acoustic measurements. In one or more embodiments, the main new features are the embedding of the fiber optic in the drilling system. The end of the fiber optic is in contact with the drilling fluid, and this would not harm the fiber termination.

[0031] The fiber optic is sensitive to the surrounding conditions, and by design, it is meant to capture strain changes that are correlated with the changes in temperature and flow conditions through the acoustic field generated. The optical fiber also captures the surrounding acoustic field and, therefore, it acts as the acoustic sensor. The optical fiber can measure both temperature and acoustic field along the whole fiber. This is known as DAS using fiber optic. Thus, the fiber optic is the acoustic sensor. The acoustic field is measured through the optical fiber, the changes in the pressure field around the optical fiber induce changes in the acoustic field, these changes are captured by the optical fiber through changes in the back scattered light to the interrogator that translates these changes into acoustic signals. Alternatively, a reference point acoustic measurement (microphone) could be used in the smart fiber optic embedded sensor design.

[0032] The sensor system can be powered through surface a laser box and do not need for downhole power system. In cases involving reference measurements, such as when thermocouples and/or acoustic sensors (microphones) are embedded in the smart portable protector, a power source (such as a rechargeable battery) may also be

included to facilitate the downhole operations. Multiple smart protector devices may be positioned around drill pipe and each can be reused in multiple drilling operations, unless damaged.

[0033] While the invention has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the attached claims.

CLAIMS

What is claimed is:

1. An apparatus for measuring environmental parameters along a drill string, the system comprising:

a protector disposed radially around the drill string, and

a sensor system with an optical fiber configured to collect data on environmental conditions within a wellbore through which the drill string is being inserted,

wherein the protector is made of a composite material having the sensor system and the optical fiber embedded within, and

wherein the collected data is capable of being extracted from the sensor system.

2. The apparatus of claim 1, wherein the protector further comprises at least one of a temperature sensor and an acoustic sensor.

3. The apparatus of claim 1 or claim 2, wherein the protector further comprises a power supply attached to the sensor system.

4. The apparatus of any of claims 1-3, wherein the sensor system is configured to perform at least one of distributed acoustic sensing and optical frequency domain reflectometry.

5. The apparatus of any of claims 1-4, wherein the sensor system is comprises an optical fiber embedded in the protector and an arrangement of optical components coupled to the embedded optical fiber located outside of the wellbore, wherein the optical components comprise a laser, photodetector, and optical signal processing elements.

6. The apparatus of any of claims 1-5, wherein the protector is a non-rotating protector.

7. The apparatus of claim 6, wherein the non-rotating protector further comprises:

an upper collar; a lower collar; and a protector sleeve,

wherein the sensor system and optical fiber are embedded within the protector sleeve of the non-rotating protector,

wherein the upper collar and lower collar connects to the drill string holding the protector sleeve at a location along the drill string, and

wherein the protector sleeve has an outer diameter greater than the drill string in order to create standoff between the drill string and the wellbore during drilling operations.

8. A method of collecting data on environmental conditions within a wellbore, the method comprising:

disposing a sensor system onto a matrix substrate of a protector;

coating the sensor system and matrix substrate with a composite material;

curing the composite material so as to embed the sensor system within the protector;

forming a protector around a drill string to be inserted into the wellbore;

using the sensor system to collect data from within the wellbore upon insertion of the drill string and protector; and

retrieving the collected data for processing.

9. The method of claim 8, further comprising:

coupling at least one of a temperature sensor and an acoustic sensor to the sensor system.

10. The method of claim 8 or claim 9, further comprising:

coupling a power supply to the sensor system.

11. The method of any of claims 8-10, further comprising:

configuring the sensor system to perform at least one of distributed acoustic sensing and optical frequency domain reflectometry.

12. The method of any of claims 8-11, further comprising:

coupling an arrangement of optical components located outside of the wellbore to the embedded optical fiber,

wherein the sensor system comprises an optical fiber embedded in the protector and the arrangement of optical components comprise a laser, photodetector, and optical signal processing elements.

13. The method of any of claims 8-12, wherein the protector is a non-rotating protector.

14. The method of claim 13, wherein the non-rotating protector further comprises:

an upper collar; a lower collar; and a protector sleeve,

wherein the sensor system and optical fiber are embedded within the protector sleeve of the non-rotating protector,

wherein the upper collar and lower collar connects to the drill string holding the protector sleeve at a location along the drill string, and

wherein the protector sleeve has an outer diameter greater than the drill string in order to create standoff between the drill string and the wellbore during drilling operations.

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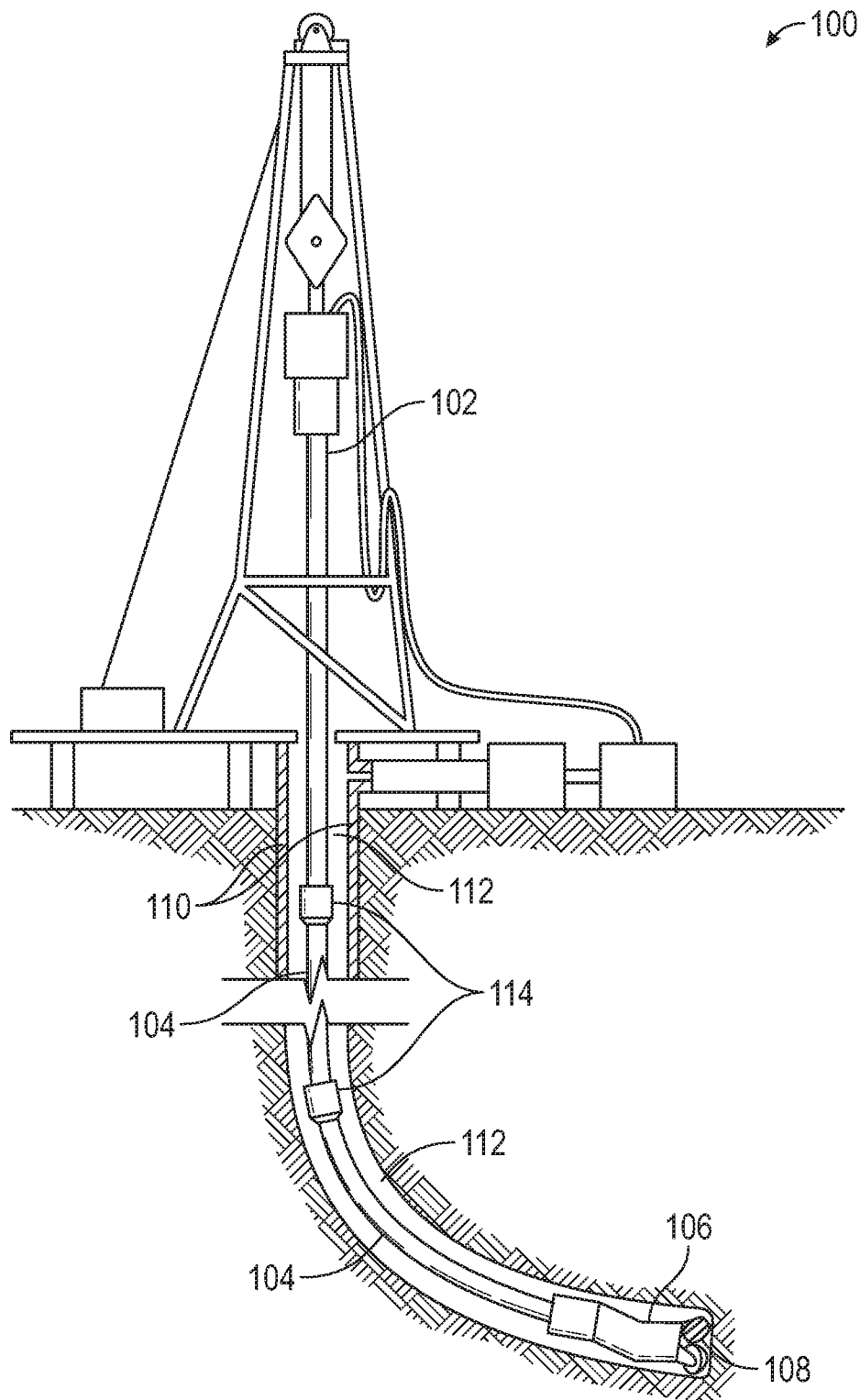


FIG. 1

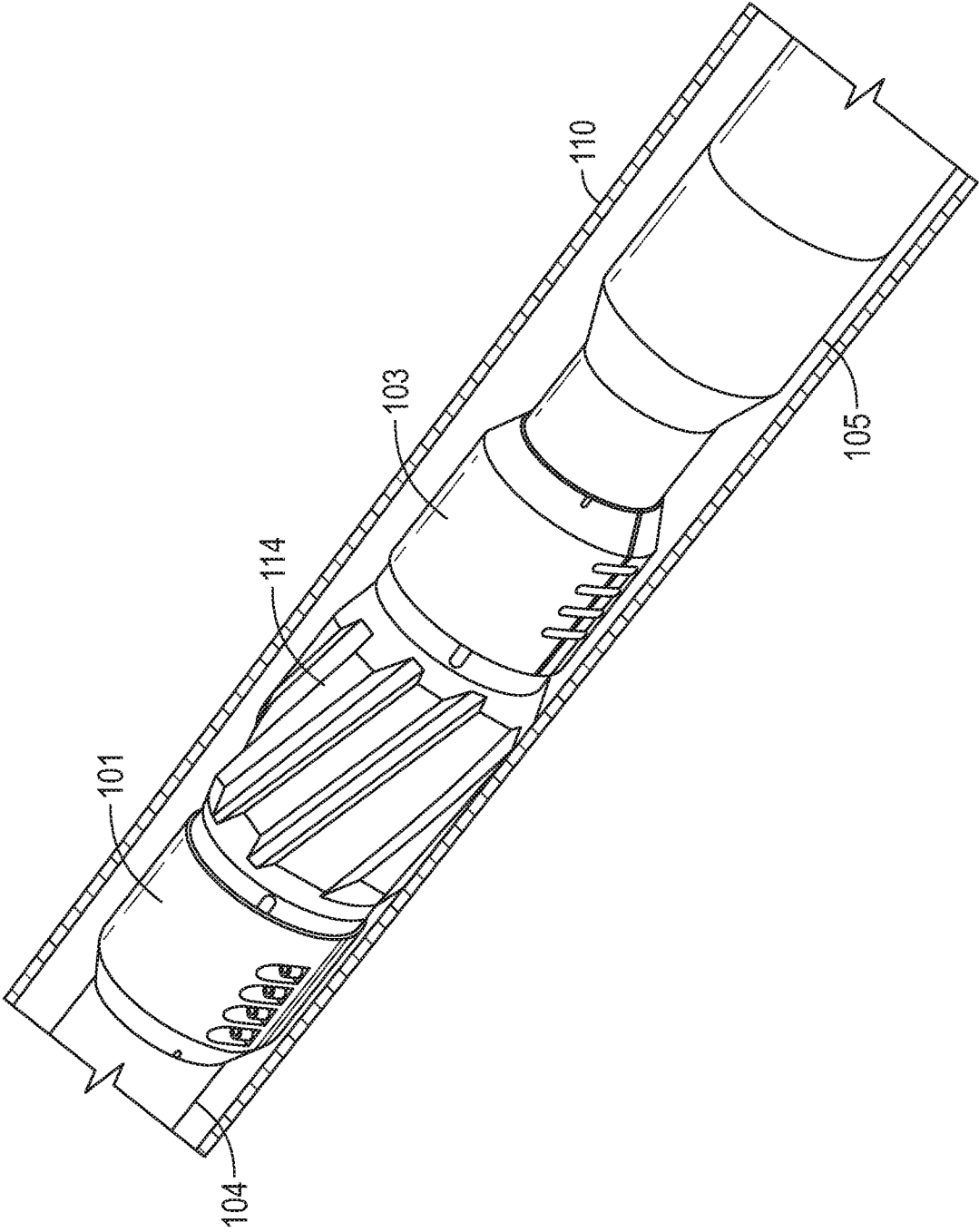


FIG. 2

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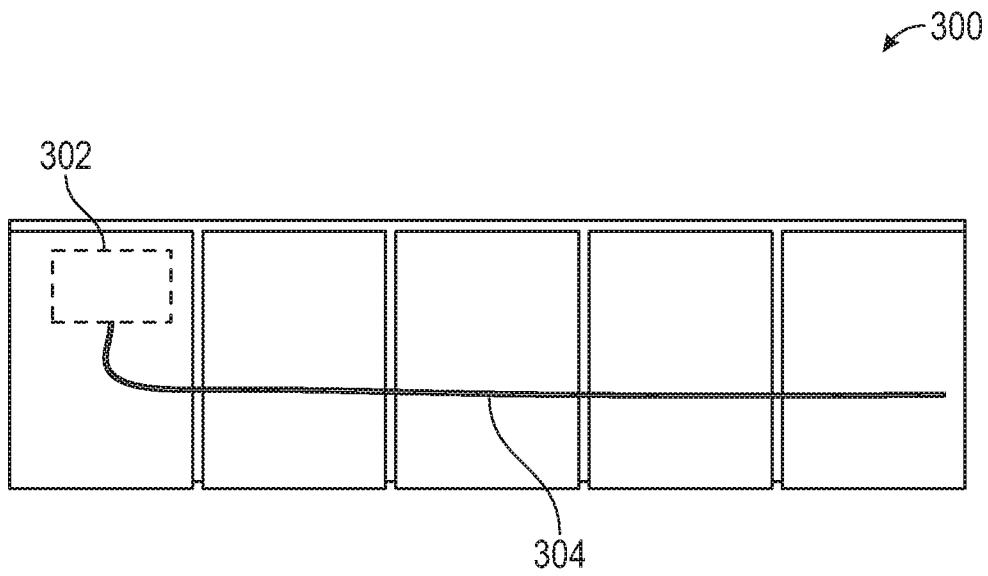


FIG. 3

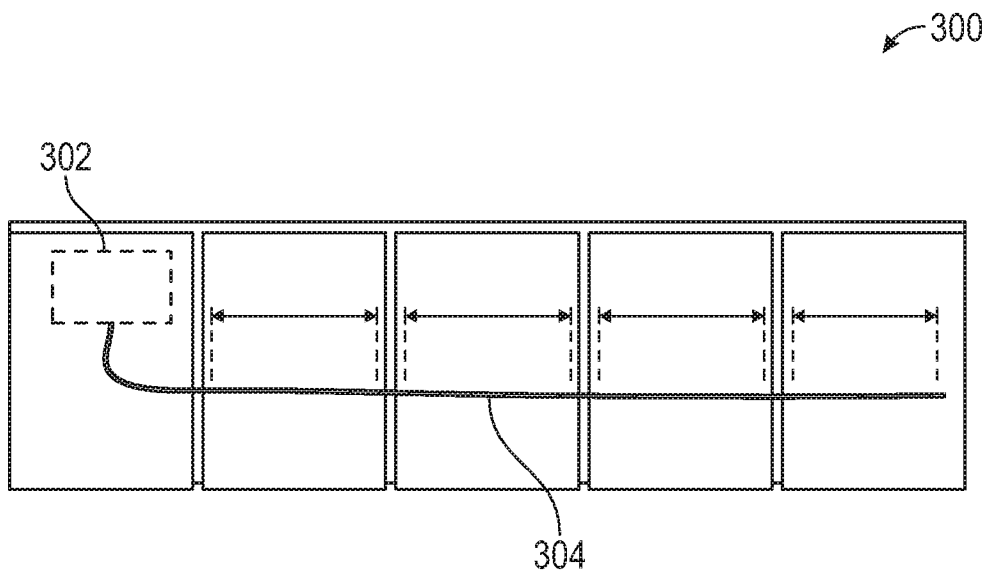


FIG. 4

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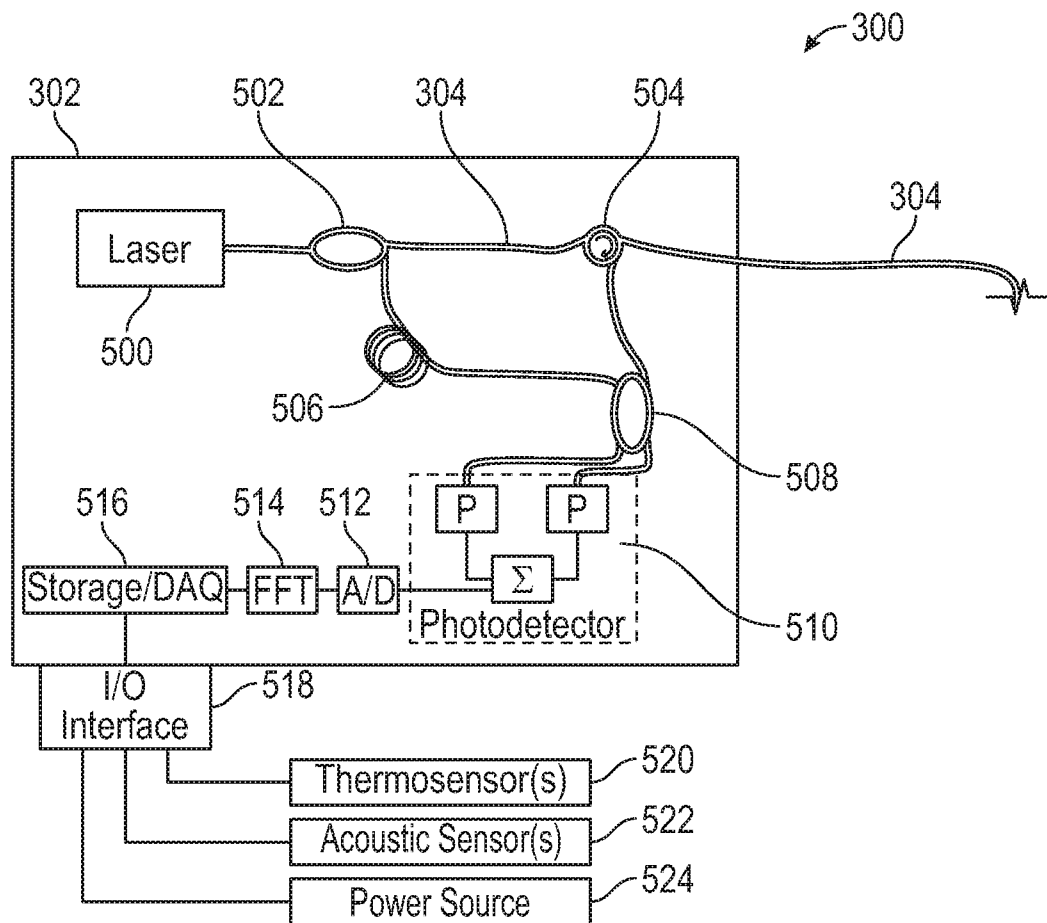


FIG. 5

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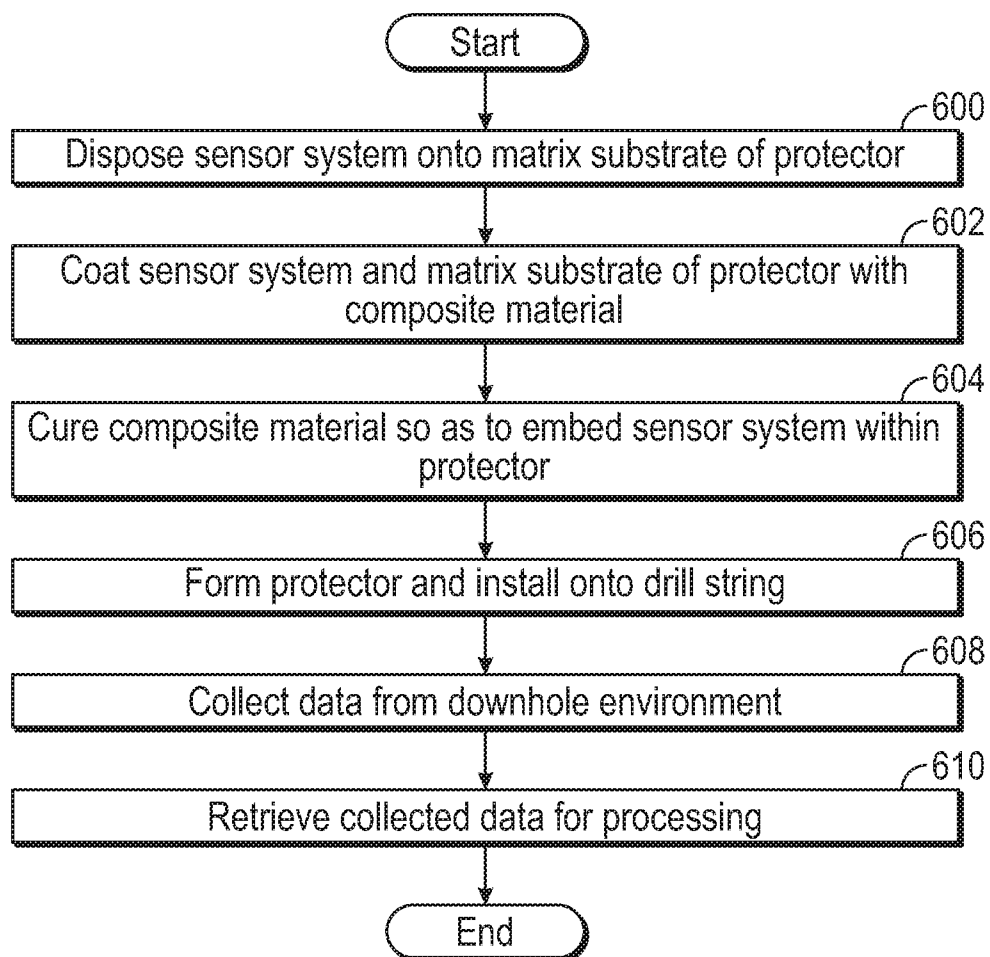


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/050692

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B47/017
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

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X A	US 2002/007945 A1 (NEUROTH DAVID [US] ET AL) 24 January 2002 (2002-01-24) abstract figure 1 figures 2-4 paragraphs [0008] - [0009], [0018], [0024] -----	1-6,8-13 7,14
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X	WO 2012/062328 A1 (NKT FLEXIBLES IS [DK]; WEPPENAAR NICKY [DK] ET AL.) 18 May 2012 (2012-05-18) abstract figures 1-4 ----- -/-	1,8



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

27 March 2021

Date of mailing of the international search report

08/04/2021

Name and mailing address of the ISA/

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Ing, James

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/050692

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2020/050692

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