(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 085 989**
B1

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **20.09.89**

(21) Application number: **83101245.5**

(22) Date of filing: **09.02.83**

(51) Int. Cl.[4]: **E 21 B 23/10**, E 21 B 47/00, E 21 B 29/02 // G01V1/40, G01V3/18, G01V5/04, G01V7/00

(54) **Downhole instrument and methods of manufacturing and using the same.**

(30) Priority: **09.02.82 US 347304**

(43) Date of publication of application: **17.08.83 Bulletin 83/33**

(45) Publication of the grant of the patent: **20.09.89 Bulletin 89/38**

(84) Designated Contracting States: **BE CH LI LU NL**

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EP 0 085 989 B1

Courier Press, Leamington Spa, England.

Description

This invention pertains generally to bore hole drilling and surveying, and more particularly to a downhole instrument and methods of manufacturing and using the same.

In the drilling of oil wells and other bore holes in the earth, it is at times necessary to determine the location of the drill or the precise location of the hole at a substantial distance below the surface of the earth. For this purpose, a surveying probe is inserted into the hole, and date from the probe is analyzed at the surface to determine the location of the probe. It is also desirable to determine the direction in which the drill is progressing and to control this direction (c.f. GB—A—1 306 781).

In the known downhole surveying equipment the probe comprises an elongated, rigid body with an inflexible metal shell. Probes of this type are incapable of travelling around bends of relatively short radius (e.g., a 150 to 300 mm radius in a hole having a diameter on the order of 19 to 25 mm), and therefore, they cannot be used in some holes.

Tools have also been provided for cutting and severing tubing, drill pipe and casing in a bore hole. Such tools generally have one or more remotely detonated explosive charges mounted in an elongated, rigid housing. Tools of this type are subject to the same limitations and disadvantages as the surveying and logging instruments heretofore provided in that they cannot travel around bends of relatively short radius and are not suitable for use in some holes.

It is in general an object of the invention to provide a new and improved downhole instrument and methods of manufacturing and using the same.

Another object of the invention is to provide an instrument and method of the above character which can also be utilized in the guidance of a downhole drill.

Another object of the invention is to provide an instrument and method of the above character which can be utilized in the cutting or severing of tubing, drill pipe and casing.

Another object of the invention is to provide an instrument and method of the above character which are suitable for use in holes having bends of relatively short radius.

Another object of the invention is to provide an instrument of the above character which is economical to manufacture.

These objects are achieved in accordance with the invention by the package and method, respectively, described in claims 1 and 10.

Preferred embodiments of the package of the invention are described in claims 2 to 9.

The invention is further described with reference to the drawings in which:

Figure 1 is a schematic diagram of one embodiment of a bore hole surveying system incorporating the invention, with the flexible probe being inserted into a bore hole and passing around a bend.

Figure 2 is a block diagram of the surveying system of Figure 1.

Figure 3 is an enlarged sectional view, partly broken away, of the flexible probe of the embodiment of Figure 1.

As illustrated in Figure 1, the surveying system includes an elongated, flexible probe 11 which is inserted into a hole 12 to be surveyed. The hole 12 can be a bore hole in the earth, as illustrated, or any other elongated opening of limited diameter such as the opening in a pipe or tubing. The probe 11 has a generally circular cross section, with an outer diameter slightly smaller than the inner diameter of the hole, e.g., for a hole diameter on the order of 19 to 25 mm, the probe would have a diameter on the order of 18 to 24 mm. The length of the probe 11 is substantially greater than the diameter, and a probe 11 having a diameter of 18 mm could, for example, have a length on the other of 1,2 m.

A flexible logging cable 16 extends in an axial direction from one end of the probe 11 and carries electrical power and signals between the probe 11 and equipment at the surface of the earth. This cable 16 is of conventional design and has a plurality of flexible electrical conductors interleaved with a plurality of reinforcing strands of suitable material such as stainless steel. The cable 16 is stored on a cable reel 18 at the surface of the earth, and the amount of cable 16 fed into the hole 12 is monitored by a cable length indicator 19 connected to the reel.

At the surface of the earth, the probe is interfaced with a microcomputer 17 by a suitable interface unit 20. The computer 17 processes the signals from the probe and the cable depth indicator to determine the location and/or orientation of the hole in the region where the probe is located.

As illustrated in Figure 2, probe 11 includes a payload such as three orientation sensors 21—23 which provide electrical signals corresponding to the orientations of the sensors relative to orthogonal reference axes. In this embodiment, the reference axis of sensor 21 is aligned with the axis of the probe 11, and the axes of sensors 22, 23 are aligned in perpendicular radial directions. Sensors 21—23 can be any suitable sensors of known design, including fluxgate compasses and other magnetometers. As used herein, the term magnetometer includes any instrument capable of detecting natural or artificial flux lines, two common types of magnetometers being Hall effect devices and flux gate transformer systems. Other suitable sensors include gyroscopes and other inertial devices. Sensors 21—23 are connected to cable 16 through an electrical power and signal conditioning module 26 in the probe 11. The probe also includes an inclinometer 27 which provides a signal corresponding to the orientation of the probe 11 about a pitch axis. If desired, additional inclinometer can be included to provide additional information such as the dip angle of the tool. Suitable inclinometers include accelerometers, electrolytic levels, and pendulous devices. Electrical connections between the cable 16, the power and signal conditioning module 26 and the elements within the probe 11 are made by a connector 28 of suitable known design.

Sensors 21—23, module 26, inclinometer 27 and connector 28 are spaced apart along the axis of probe 11 and are interconnected by flexible electrical conductors 31 (Fig. 3). Alternatively, the electrical components can be fabricated on a flexible circuit board, or on a board having a plurality of relatively short, rigid sections interconnected by one or more flexible sections. These elements are encased within an elongated, flexible casing 32 of high tensile strength. The casing 32 is closed and secured to a stainless steel nose piece 33 by a clamp 34 at the distal end of the probe 11, and at the proximal end the casing 32 is affixed by a clamp 35 to connector 28 and thus to logging cable 16.

In one presently preferred embodiment, casing 32 comprises a fabric woven or braided of fibers having a high tensile strength, i.e., a tensile strength greater that that of stainless steel, preferably $1.725 \cdot 10^6$ Pa or more. One presently preferred fabric is an aromatic polyamide fiber manufactured by DuPont under the trademark Kevlar. This fiber has a tensile strength on the order $2.756 \cdot$ Pa. Other suitable fibers of high tensile strength can also be employed, including graphite fibers, glass fibers, nylon (Registered Trademark) fibers and boron fibers.

The interior of casing 32 is filled with a mass of flexible, electrically insulative material 36 which surrounds the sensors 21, 22, 23 and other electrical components 26, 27, 28 and provides cushioning for them. This material 36 and the outer casing 32 form a flexible body which can pass freely around bends of relatively short radius in the bore hole 12. Suitable materials include silicones and other synthetic rubber materials such as Devcon (Registered Trademark) polyurethane or a silicone rubber sold under the name Silastic (Registered Trademark). The flexible material 36 can be either in a solid form or in a fluid form. Suitable fluid materials include silicones and fluorocarbons of high dielectric constant and low vapor pressure. The fluid can be in the form of a gel, and it preferably has a relatively high viscosity. One particularly suitable fluid material is a silane polymer known as Dow Corning (Registered Trademark) 200 fluid. Alternatively, with a solid cushioning material, the fabric casing 32 can be omitted, and axially extending fibers can be embedded in the mass of material 36 to provide the desired tensile strength, in which case it is desirable that the fibers be able to move axially within the mass of material 36 to avoid collapsing of the body as it is bent.

The outer surface of casing 32 can be coated with a lubricious material such as polytetrafluoroethylene (Teflon, Registered Trademark) which facilitates the free passage of probe 11 through the bore hole 12. A flexible sealing ring 41 is affixed to the outer wall of the probe 11 toward the proximal end thereof to facilitate driving the probe 11 through a bore hole 12, as discussed hereinafter. The other diameter of the seal is chosen to provde sliding, sealing engagement with the inner wall of the opening in which the probe 11 is to be used, and seals of different sizes and shapes can be mounted interchangeably for casings of different diameters. The seal can be bypassed with flow passagways (not shown) to prevent the formation of a vacuum behind the head of the probe as it is withdrawn from the hole.

In one presently preferred method of manufacture, the electrical components 21—23, 26, 27, 28 of the probe 11 are connected together and suspended vertically from cable 16 in the desired spaced apart relationship. Casing 32 is positioned coaxially of these components, with the open end of the casing 32 facing in an upward direction. The fluid silicone rubber material is then proured into the casing to form the flexible body. Connector 28 is installed and connected electrically to the leads 31 in the probe 11 and to the conductors of cable 16, the open end of the casing 32 is drawn about the connector, and clamp 33 is installed.

With a solid cushioning material, the material 36 can be formed about the electrical components 21—23, 26, 27, 28 in one or more successive layers, with adjacent ones of the layers being able to move somewhat relative to each other. The components 21—23, 26, 27, 28 and cushioning material 36 are then inserted into the fabric casing 32 as a unit.

In use, probe 11 is inserted into the upper portion of the hole 12 to be surveyed or drilled, and pressurized fluid (e.g., water or air) is applied to the hole 12 above the probe 11 to drive the probe 11 down through the hole 12 in piston-like fashion, with seal 41 forming a seal between the body of the probe 11 and the wall of the casing 32 or other opening in which the probe 11 is inserted. In the event that fluid is trapped in the hole ahead of the probe 11, it can be removed by any suitable means, e.g., by pumping it out of the hole 12, by withdrawing it from the hole 12 by the cable 16, or by driving it into the formation surrounding the hole 12. When the probe 11 reaches a bend in the hole 12, the body flexes, and the probe 11 passes freely around the bend. As discussed above, the probe can travel around bends of relatively short radius, e.g., a bend having a radius of 150 mm in a hole having a diameter of 19 to 25 mm. The probe 11 is withdrawn from the hole by drawing on the logging cable 16.

Because of its relatively small diameter, probe 11 is also suitable for use in the guidance of a downhole drilling system. In this application, the probe 11 is mounted in the drill motor housing itself or in a fluid passageway near the drill head, and cable 16 extends to the surface through the fluid passageway or another suitable passageway in the well casing. At the surface, the signals from the probe are processed and utilized to control the direction of the drill.

In addition to direction sensors, the payload or instrumentation within the probe 11 can include other sensors for other logging functions, e.g., temperature, pressure, nuclear radiation, hydrogen ion concentration, and instruments for measuring the characteristics of the formation being drilled.

The invention is also useful in tools for cutting or severing drill pipes, tubing and/or casing in a bore hole. A tool of this type made in accordance with the invention is similar to the instrument of Figures 1 and 3, with electrically detonated explosive charges instead of sensors 21—23. The explosives can be any suitable explosives of known composition, e.g., pellets or plastic explosives. Electrical detonating signals are applied to the explosives by cable 16 and the electrical leads within the probe. The charges can be arranged to provide any type of cutting action required, e.g., a concentrated explosion for severing a drill head from the end of a tube, or a series of explosions for perforating a line as the probe passes through it.

It is apparent from the foregoing that a new and improved downhole probe and methods of manufacturing and using the same have been provided. While only certain presently preferred embodiments have been described in detail, as will be apparent to those familiar with the art, certain changes and modifications can be made without departing from the scope of the invention as defined by the following claims.

Claims

1. A package for carrying a payload (21, 22, 23, 27) in a bore hole (12) in the earth comprising an axially elongated casing (32) of flexible material having a high tensile strength, an elongated mass of flexible, cushioning material (36) surrounding the payload (21, 22, 23, 27) and filling the casing (32) to form a flexible probe (11) which can be propelled through the bore hole (12) in piston-like fashion by pressurized fluid and can travel around bends of relatively short radius in the bore hole, and a flexible cable (16) extending axially from one end of the probe (11) and secured to the casing (32) of flexible material for carrying signals between the payload (21, 22, 23, 27) and the surface of the earth.

2. The package of Claim 1 wherein the payload comprises a plurality of sensors (21, 22, 23, 27) spaced axially within the flexible probe (11) for providing electrical information signals.

3. The package of Claim 2 wherein at least one of the sensors (21, 22, 23, 27) is selected from the group consisting of magnetometers, accelerometers, gyroscopes and inertial devices.

4. The package of Claim 1 wherein the payload (21, 22, 23, 27) comprises an explosive detonated by signals applied to the cable (16).

5. The package of Claim 1 wherein the casing (32) is fabricated of fabric.

6. The package of Claim 5 wherein the fabric comprises fibers selected from the group consisting of aromatic polyamide fibers, glass fibers, graphite fibers, boron fibers, nylon fibers, and combinations thereof.

7. The package of Claim 1 wherein the cushioning material (36) comprises a silicone rubber.

8. The package of Claim 1 wherein the cushioning material (36) is in a fluid state.

9. The package of Claim 1 wherein the outer surface of the casing (32) is coated with a lubricious material.

10. A method of manufacturing an instrument for use in a bore hole (12) in the earth, comprising the steps of: spacing a plurality of payload elements (21, 22, 23, 27) along an axis, interconnecting the payload elements (21, 22, 23, 27) flexible electrical conductors (31), connecting a flexible cable (16) to the payload elements (21, 22, 23, 27) for carrying signals between the payload elements (21, 22, 23, 27) and the surface of the earth, placing a casing (32) of flexible, high tensile strength material around the payload elements (21, 22, 23, 27) and the conductors (31), affixing the cable (16) to the flexible casing (32), and filling the casing (32) with a mass of flexible cushioning material (36) which surrounds the payload elements (21, 22, 23, 27) and the conductors (31) to form a flexible probe (11) capable of travelling around bends of relatively small radius in the bore hole (12).

Patenstansprüche

1. Behälter zum Verbringen einer Nutzlast (21, 22, 23, 27) in ein Erd-Bohrloch (12), mit einer in Axialrichtung länglichen Hülle (32) aus flexiblem Material mit hoher Zugfestigkeit, eine länglichen Masse aus flexiblem, die Nutzlast (21, 22, 23, 27) umgebendem Dämpfungsmaterial (36), das die Hülle (32) ausfüllt und zusammen mit dieser eine flexible Sonde (11) bildet, die mittels eines Druckfluids kolbenartig durch das Bohrloch (12) vorgeschoben werden kann und im Bohrloch um Biegungen mit verhältnismäßig kurzem Radius beweglich ist, und einem sich in Axialrichtung von einem Ende der Sonde (11) wegerstreckenden und an der Hülle (32) aus flexiblem Material befestigten flexiblen Kabel (16) zur Übermittlung von Signalen zwischen der Nutzlast (21, 22, 23, 27) und der Erdoberfläche.

2. Behälter nach Anspruch 1, wobei die Nutzlast mehrere innerhalb der flexiblen Sonde (11) axial in Abständen voneinander angeordnete Sensoren (21, 22, 23, 27) zur Übermittlung elektrischer Informationssignale umfaßt.

3. Behälter nach Anspruch 2, wobei wenigstens einer der Sensoren (21, 22, 23, 27) aus einem Magnetometer, einem Beschleunigungsmeßgerät, einem Gyroskop oder einer Trägheitseinrichtung besteht.

4. Behälter nach Anspruch 1, wobei die Nutzlast (21, 22, 23, 27) einen Sprengstoff enthält, der durch

dem Kabel (16) zugeführte Signale gezündet wird.

5. Behälter nach Anspruch 1, wobei die Hülle (32) aus Stoff hergestellt ist.

6. Behälter nach Anspruch 5, wobei der Stoff Polyamidfasern, Glasfasern, Graphitfasern, Borfasern, Nylonfasern oder Kombinationen dieser Fasern enthält.

7. Behälter nach Anspruch 1, dadurch gekennzeichnet, daß das Dämpfungsmaterial (36) Silikonkautschuk enthält.

8. Behälter nach Anspruch 1, wobei sich das Dämfungsmaterial (36) in einem fluiden Zustand befindet.

9. Behälter nach Anspruch 1, wobei die äußere Oberfläche der Hülle (32) mit einem Schmiermittel überzogen ist.

10. Verfahren zur Herstellung eines Instruments zur Verwendung in einem Erd-Bohrloch (12) mit folgenden Schritten: Anordnen mehrerer Nutzlastelemente (21, 22, 23, 27) längs einer Achse, Verbinden der Nutzlastelemente (21, 22, 23, 27) mit flexiblen elektrischen Leitern (31), Verbinden eines flexiblen Kabels (16) mit den Nutzlastelementen (21, 22, 23, 27) zur Übertragung von Signalen zwischen den Nutzlastelementen (21, 22, 23, 27) und der Erdoberfläche, Anordnen einer Hülle (32) aus flexiblem hoch-zugfestem Material um die Nutzlastelemente (21, 22, 23, 27) und die Leiter (31), Befestigen des Kabels (16) an der flexiblen Hülle (32) und Füllen der Hülle (32) mit einer Masse aus flexiblem Dämpfungsmaterial (36), das die Nutzlastelemente (21, 22, 23, 27) und die Leiter (31) umgibt, so daß eine flexible Sonde (11) entsteht, die um Biegungen mit verhältnismäßig kleinem Radius in dem Bohrloch (12) beweglich ist.

Revendications

1. Equipement pour transporter une charge utile (21, 22, 23, 27) dans un trou de forage (12) dans la terre, comprenant une enveloppe (32) axialement allongée, de matière flexible ayant une grande résistance à la traction, une masse allongée de matière amortisseuse flexible (36) entourant la charge utile (21, 22, 23, 27) et remplissant l'enveloppe (32) pour former une sonde flexible (11) qui peut être propulsée à travers le trou de forage (12), à la façon d'un piston, par un fluide sous pression, et qui peut franchir des courbes de rayon relativement petit dans le trou de forage, et un câble flexible (16) s'étendant axialement à partir d'une extrémité de la sonde (11) et fixé à l'enveloppe (32) de matière flexible pour transmettre des signaux entre la charge utile (21, 22, 23, 27) et la surface du sol.

2. Equipement suivant la revendication 1, dans lequel la charge utile comprend plusieurs capteurs (21, 22, 23, 27) répartis axialement à l'intérieur de la sonde flexible (11) pour fournir des signaux électriques d'information.

3. Equipement suivant la revendication 2, dans lequel au moins l'un des capteurs (21, 22, 23, 27) est choisi dans le groupe comprenant des magnétomètres, des accéléromètres, des gyroscopes et des dispositifs inertiels.

4. Equipement suivant la revendication 1, dans lequel le charge utile (21, 22, 23, 27) comprend un explosif à faire détoner par des signaux appliqués au câble (16).

5. Equipement suivant la revendication 1, dans lequel l'enveloppe (32) est faite de tissu.

6. Equipement suivant la revendication 5, dans lequel le tissu comprend des fibres choisies dans le groupe comprenant des fibres de polyamides aromatiques, des fibres de verre, des fibres de graphite, des fibres de bore, des fibres de nylon et des combinaisons de ces fibres.

7. Equipement suivant la revendication 1, dans lequel la matière amortisseuse (36) comprend du caoutchouc de silicone.

8. Equipement suivant la revendication 1, dans lequel la matière amortisseuse (36) est à l'état fluide.

9. Equipement suivant la revendication 1, dans lequel la surface extérieure de l'enveloppe (32) est revêtue d'une matière à caractère lubrifiant.

10. Procédé de fabrication d'un instrument destiné à être utilisé dans un trou de forage (12) dans la terre, comprenant les étapes consistant à répartir plusieurs éléments de charge utile (21, 22, 23, 27) le long d'un axe, à connecter entre eux les éléments de charge utile (21, 22, 23, 27) par des conducteurs électriques flexibles (31), à connecter un câble flexible (16) aux éléments de charge utile (21, 22, 23, 27) pour faire passer des signaux entre les éléments de charge utile (21, 22, 23, 27) et la surface du sol, à placer une enveloppe (32) de matière flexible à grande résistance à la traction autour des éléments de charge utile (21, 22, 23, 27) et des conducteurs (31), à fixer le câble (16) à l'enveloppe flexible (32) et à remplir l'enveloppe (32) d'une masse de matière amortisseuse flexible (36) qui entoure les éléments de charge utile (21, 22, 23, 27) et les conducteurs (31) pour former une sonde flexible (11) capable de franchir des courbes de rayon relativement faible dans le trou de forage (12).

FIG. 1

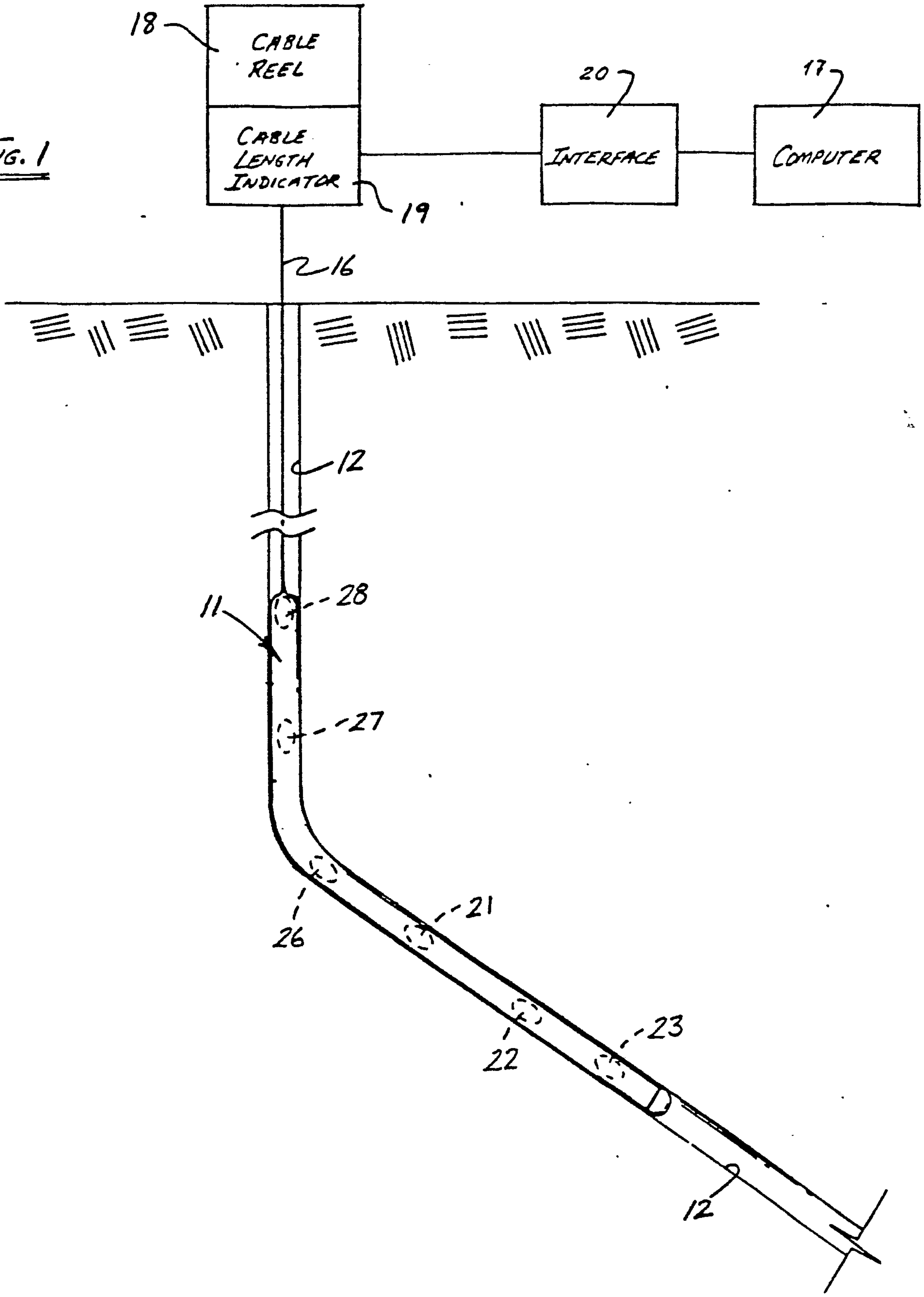
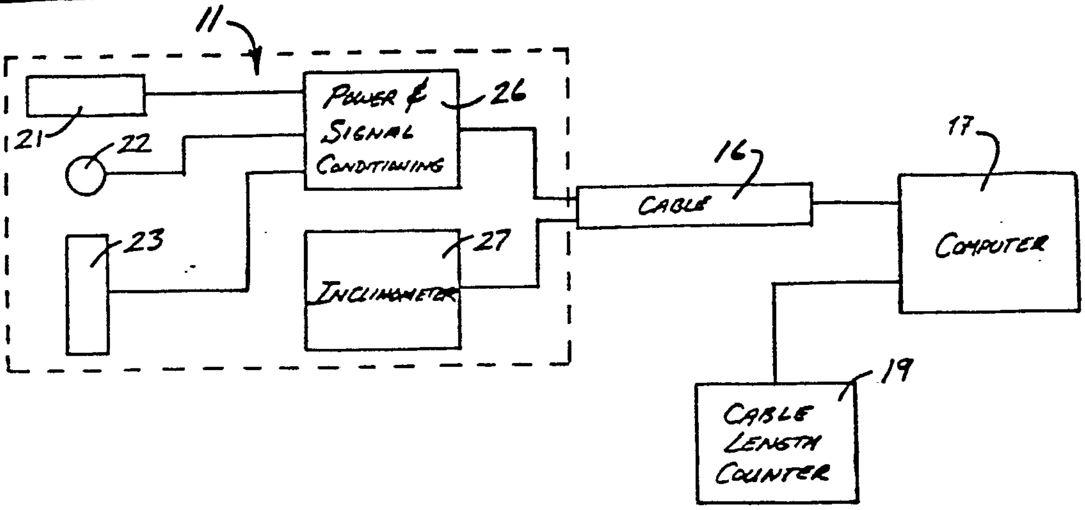

18
CABLE REEL
CABLE LENGTH INDICATOR
19
20
INTERFACE
17
COMPUTER
16
12
11
28
27
26
21
22
23
12

FIG. 2


11
21
22
23
POWER & SIGNAL CONDITIONING
26
INCLINOMETER
27
CABLE
16
COMPUTER
17
CABLE LENGTH COUNTER
19

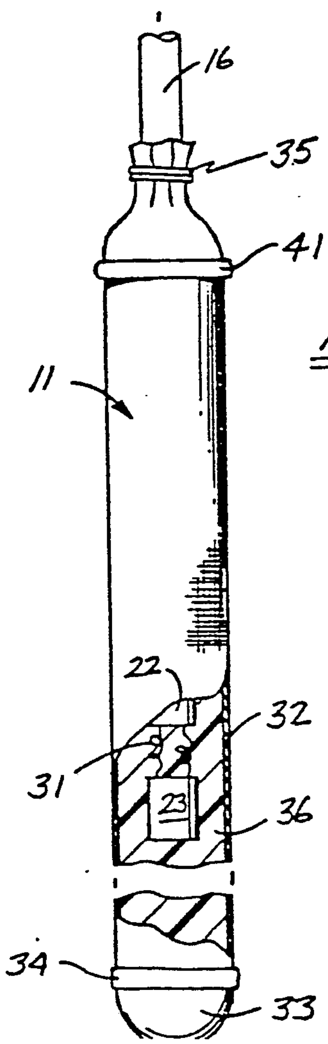

16
35
41
11
22
32
31
23
36
34
33

FIG. 3