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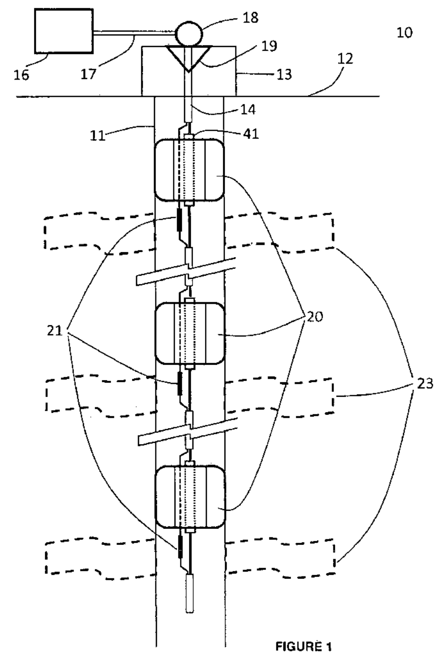

FIGURE 1

(57) Abstract: A multi-zone monitoring system allowing simultaneous measurement of separate zones of multi-zone wellbore formations comprising a multi-component umbilical containing both electrical lines and a hydraulic fluid lines, an inflatable isolation packer that can traverse through the wellbore and be inflated with hydraulic fluid to seal off a portion of the wellbore wherein the inflatable isolation packer is connected to a hydraulic line of the multi-component umbilical, wherein the inflatable isolation packer further comprises: one or more cable bypass feed throughs for the umbilical's electric and hydraulic fluid lines, wherein the hydraulic line is attached to the inflatable isolation packer with compression fittings. A method of monitoring geologic formations in a wellbore comprising attaching a plurality of inflatable isolation packers at predetermined distance to an umbilical containing a hydraulic line for inflating each packer, monitoring each connection of the hydraulic line to each inflatable isolation packer, attaching monitoring equipment to the umbilical at predetermined distances to the umbilical, lowering the equipment and inflatable isolation packers down a wellbore using the umbilical, and monitoring the equipment and each hydraulic line connection at a surface.

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AN APPARATUS, SYSTEM AND METHOD FOR MULTI ZONE MONITORING IN BOREHOLES

RELATED APPLICATIONS

[0001] This application claims the benefit of and priority to Provisional Application entitled Apparatus, System and Method for Multi Zone Monitoring in Boreholes filed September 10, 2013, assigned application Serial No. 61/876,190 and which is incorporated by reference herein in its entirety.

FIELD OF THE DISCLOSURE

[0002] The invention relates to an apparatus, system and method for deploying, suspending, retrieving and monitoring multiple downhole logging tools, positioned between zonal isolation packers, from a surface deployment unit. In particular, the invention relates, but is not limited, to isolating multiple separate geological formations penetrated by a single borehole and monitoring the pressure and temperature of the fluid-filled pores in each formation.

BACKGROUND TO THE DISCLOSURE

[0003] Reference to background art herein is not to be construed as an admission that such art constitutes common general knowledge.

[0004] Borehole monitoring, particularly across multiple zones (e.g. two to 10+), is a relatively complicated, time consuming, and expensive operation. Heavy tubing deployed systems, typically connected to a surface control and measurement system using electric and hydraulic control lines strapped to the tubing, along with an expensive drilling or workover rig, have been known to be used for such borehole monitoring operations. An expensive drilling or workover rig typically includes a frame that provides support for various components such as a drill head support structure, which would usually include a drill string capable of drilling a borehole.

[0005] One aspect of borehole monitoring that is identified as being particularly onerous is the requirement of a drilling rig and heavy duty tubing to deploy and retrieve any monitoring system. Typically the borehole pressure and temperature is monitored by drilling a borehole and installing some form of tubing in the hole. At the required depths of the tubing, special tools such as isolating packers and pressure / temperature sensors are attached as required. Typically an electrical cable is installed with the tubing to provide telemetry to the sensors and a hydraulic cable is also installed to provide inflation control to the isolation packers.

[0006] Once the monitoring system has gathered all the required data, however, the monitoring system, isolating system and tubing must then be retrieved. Typically, system retrieval involves the use of a drilling rig. The time and cost associated with recovering the monitoring systems in this manner renders multi-zone borehole monitoring impractical for non-permanent applications.

[0007] Some efforts have been made to reduce the problems, such as by using battery powered sensors that record data to a local memory device and which are deployed on solid wire spooled off wireline units and surface winches without the requirement for a drilling rig. Pressure readings can then be obtained at any depth of the borehole without having to install or retrieve a tubing string. However this technique does not provide for real time data, or the ability to isolate various zones or sections of the borehole, and so is not suited for applications requiring continuous monitoring of borehole or geological properties in a multi-zone setting.

[0008] A further problem with isolating and monitoring these zones is associated with legislation requirements for abandoning old boreholes. Typically the isolating packers used are expensive tubing mounted devices that are not capable of being retrieved due to their mechanical setting design and that often require use of drilling rigs with expensive specialist equipment to remove these devices from the borehole and satisfy legislation requirements.

[0009] Having a borehole isolating and monitoring system which can be deployed, suspended and retrieved from a portable surface winch is therefore an attractive yet unavailable system. It is desirable to be able to deploy a plurality of sensors at different depths in order to isolate the borehole sections above and below each sensor. The sensors could be powered from an autonomous surface cabinet that could also display and record real-time data. The provision of surface electrical power would eliminate the need for battery powered downhole sensors, which otherwise would need to be retrieved periodically to recharge or replace the batteries.

OBJECT OF THE DISCLOSURE

[0010] It is an aim of this invention to provide an apparatus, system and method for deploying, suspending and retrieving a multi-zone borehole monitoring system from a portable surface winch which enables economical, regulatory-compliant downhole monitoring, real time data collection, and eventual retrieval.

[001 1] Other preferred objects of the present invention are apparent from the following description.

SUMMARY OF DISCLOSURE

[0012] According to a first aspect of the disclosure, there is provided a retrievable, multi-zone downhole monitoring system for use in multi-zone borehole operations, the downhole monitoring system comprising:

At least one downhole measuring instrument comprising electronic components including sensors transmitting real time data to surface; and

At least one pressure isolation packer that can be actuated from surface to provide a borehole seal;

a control and suspension umbilical comprising power and telemetry electrical cables for the sensors, a hydraulic inflation line for the packers and means of conveyance into the borehole;

pressure-testable sealed connectors to attach the control and suspension umbilical to the pressure isolation packer; and

a suspension hang off apparatus comprising umbilical slips to suspend the system and umbilical exiting ports;

wherein the measuring instruments include at least a pressure sensor or a temperature sensor, and the isolation packer is actuated from a surface to provide zonal isolation across each sensor.

Hereinafter, such a downhole measuring instrument and companion pressure isolation packer will be referred to as a zonal isolation module.

[0013] The isolation packers can include a pressure rated connections to allow all hydraulic and electrical lines to bypass through each packer. It will be appreciated that the environment of a borehole may contain significant pressure, particularly due to hydrostatic pressure of borehole fluid at a significant depth in the well. This can cause infiltration of fluids into the electrical wires and hydraulic fluid lines. The connectors are preferably located above and below each packer. Even more preferably the connectors are capable of being pressure tested prior to deployment to ensure pressure integrity. Even more preferably the connectors may provide a tertiary weak point to allow for emergency disconnect capabilities by means ensuring the connectors break from an applied tensile load less than the maximum tensile strength of the umbilical and other components.

[0014] Preferably the system is connected to a multi-core downhole umbilical on a portable winch at the surface. The multi-core downhole umbilical can be spooled into the borehole to deploy the system to the required depth. The multi-core or wire downhole umbilical allows more than one instrument or sensor to be connected to the umbilical cord. The portable winch provides a depth counter and slip ring to capture sensor measurements and attribute them to precise depths while running (raising and lowering) in the hole.

[0015] Preferably the downhole umbilical components include a data transfer system in communication with the measuring instruments and a hydraulic system for inflating and deflating the isolation packers. The downhole umbilical also provides sufficient tensile strength to accommodate the total number of packers and sensors required.

[0016] The downhole monitoring system may further comprise measuring instruments to diagnose well integrity such as vibration or chemical composition of the fluids between each isolation packer.

[0017] Preferably the downhole measuring instruments comprise a mating portion that secures to a corresponding mating portion of the downhole umbilical. Preferably the downhole tool contains the sensors, the data transfer system, and the power system. The downhole tool could be actuated from a surface control unit to retrieve real time data.

[0018] The surface control unit may comprise data storage for storing data received from the sensors. The data transfer system may store the data for transmission at a requested time. The control unit also provides power to the downhole tool and hydraulic pressure for the isolation packers.

[0019] The portable surface winch is used to lower the downhole monitoring system through the borehole, preferably to total depth, and suspend the monitoring system by a portion of the downhole umbilical, preferably at a well head. Preferably at least a portion of the downhole umbilical protrudes from the wellhead to allow a portable surface winch to recover the system from the borehole at the end of the monitoring period.

[0020] Further features and advantages of the present invention will become apparent from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate preferred embodiments of the disclosure. These drawings, together with the general description of the disclosure given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the disclosure. By way of example only, preferred embodiments of the disclosure will be described more fully hereinafter with reference to the accompanying figures.

[0022] Figure 1 is a diagrammatic view of a multi-zone monitoring system suspended in a borehole;

[0023] Figure 2a is a diagrammatic view of a portable surface winch lowering a monitoring system into a borehole on the downhole umbilical;

[0024] Figure 2b is a diagrammatic view of a multi-zone monitoring system being lowered to total depth into a borehole;

[0025] Figure 3 is a diagrammatic view of an integral zonal isolation module comprising an isolation packer and downhole monitoring instrument;

[0026] Figure 4 is a cross-sectional view of a downhole umbilical

[0027] Figure 5 is a diagrammatic view of the wellhead suspension apparatus

DETAILED DESCRIPTION OF THE DISCLOSURE

[0028] Figure 1 illustrates a diagrammatic view of a multi-zone downhole monitoring system **10** located in a borehole **11** below surface **12.** The multi-zone downhole monitoring system **10** may be located at various depths below surface **12,** but typically the borehole **11** will be greater than 50m below surface **12** and, in many cases, approximately 1000m below surface **12.**

[0029] The multi-zone downhole monitoring system **10** has a wellhead **13** located at the top of the borehole **11** for equipment suspension and well control. The umbilical **14** provides the monitoring system **10** with power, control, and telemetry. Typically the monitoring system **10** is powered and operated at surface **12,** via surface cable **17,** and umbilical **14,** from the surface control unit **16.** Although the surface control unit **16** is illustrated as being located on the surface adjacent to the borehole **11,** it will be appreciated that the surface control unit could also be located elsewhere, such as a control office.

[0030] The multi-zone downhole monitoring system **10** has a wellhead outlet **18** connected to the wellhead **13** at the surface of the borehole. The wellhead outlet provides a sealable barrier between the borehole **11** and surface **12** allowing hydraulic and electrical connections to be connected between the downhole umbilical **14** and surface cable **17.** During suspension, the wellhead **13** uses a wellhead suspension apparatus "slips" **19,** known in the industry, to lock the umbilical in place and hold the weight of the monitoring system **10.** At pre-specified intervals, i.e., length separation, multiple isolation packers **20** are attached to the umbilical **14** to provide barriers between different geological formations **23** intersected by the borehole. Typically there may be any number of formations **23** between one to ten. Between each isolated formation **23,** downhole measuring instruments **21** are attached to the umbilical to provide real time data (typically pressure and temperature) from each isolated zone **23.** Other measurements may be taken, e.g. gas partial pressure in fluid. During monitoring operations, the isolation packers **20** are inflated to create sealing barriers between each formation while the measuring instruments monitor various formation fluid and well parameters. The monitoring information can be conveyed through the wires of the umbilical to the surface.

[0031] Figure 2a illustrates a diagrammatic view of the multi-zone monitoring system **10** being deployed at surface **12** into the borehole **11.** An isolation packer **20** and measuring instruments **21** are connected to the umbilical **14** at surface **12.** This array comprises an integral zonal isolation and monitoring module **15.** The integral zonal isolation and monitoring module **15** is then lowered through the wellhead **13,** and possibly a well control valve **31** into the opening of the borehole **11** using the portable winch **30** at surface. The umbilical is configured from the portable winch **30** over a pulley **32** above the wellhead **13** to allow smooth deployment into the borehole **11.** The portable winch **30** is used to lower the integral zonal isolation and monitoring module **15** into the borehole **11** to a depth equal to that between the deepest two zones requiring isolation **32.**

The hydraulic line contained within the umbilical is also in communication with a hydraulic pump for the inflation and deflation of the inflatable isolation packers that forms part of the surface control unit **16.** Once the first integral zonal isolation module is at a depth equal to that between the deepest two zones requiring isolation **32,** the umbilical **14** is suspended in the slips **19** and cut to allow the installation of another integral zonal isolation and monitoring module **15** on the umbilical **14.** The subsequent integral zonal isolation module **15** is connected to the cut umbilical **14** using compression fittings **40** and a pressure testable sealed connector **41**(see Figure 3) before removing the slips **19** and continuing with the deployment of the multi-zone system.

[0032] Figure 2b illustrates a diagrammatic view of the multi-zone downhole monitoring system **10** having been deployed to total depth into the borehole **11.** The steps as detailed in the description of figure 2a are repeated as required to position a sequence of integral zonal isolation and monitoring modules **15** between the target formations **23** of the borehole **11**. Each integral zonal isolation and monitoring module **15** is connected to the umbilical **14** at surface with the distance between each system matching the distance between each target formation **32.** Once the entire multi-zone downhole monitoring system **10** is installed in the borehole at the appropriate total depth, the umbilical **14** is severed at surface **12.** The umbilical **14** is suspended in the slips **19** at the wellhead **13** allowing for the weight of the multi-zone system to be suspended at the point of the slips without dropping into the hole. Figure 1 shows that the top of the hydraulic line **50** and electrical cable **51** (see Figure 3) in the severed umbilical **14** are connected at the wellhead outlet **18** to establish communication from the surface control unit **16** to the monitoring system, via surface cable **17.** It will be appreciated that the monitoring equipment of the system can be positioned on the umbilical proximate to a geologic formation intersected by the well bore.

[0033] Figure 3 illustrates a preferred integral zonal isolation and monitoring module **15.** The integral zonal isolation and monitoring module **15** has an isolation packer **20** in the form of an inflatable, pressure sealing elastomic bladder inflated and shaped to seal or "pack-off the internal diameter of the borehole **11** in Figure 1. The integral zonal isolation and monitoring module **15** has an inner mandrel **46** to provide a cylindrical shaft and bore through the center of the isolation packer to provide for a base for the isolation packer **20,** a hydraulic chamber **58** and inflate port **45** for inflation of the isolation packer **20** and contains one or more cable bypass feed throughs for the umbilical's **14** electric cable **51**. The inner mandrel **46** may also provide the ability for a "shear-release" functionality as a secondary method of deflation. The shear-release function would allow for the inner mandrel to shear under a determined applied load and therefore release the stored pressure in the packer allowing it to deflate. Located at the top and bottom of the inner mandrel **46** are compression fittings **40** and pressure testable sealed connectors **41** to provide sealed connections between the umbilical's **14** hydraulic line **50** and the inner mandrel **46.** The sealed connections **41** provide a pressure barrier to ensure pressure can be applied directly to the isolation packer's inflate port **45** and monitored at surface to ensure there is no pressure leak, this also provides the ability for the isolation packer to maintain its required inflate pressure for the life of the system without pressure leaks, further, the ability to pressure test these connections at surface provides confidence to the systems integrity prior to deployment down a borehole. The isolation packers are inflated by use of a common hydraulic line **50** in the umbilical **14.** When hydraulic pressure is applied from the surface control unit **16** (see Figure 1) to the line **50,** all isolation packers are inflated to create a barrier seal against the bore hole walls.

[0034] The umbilical **14** also houses electrical cable **51** for the monitoring sensors, i.e., instruments. Typically, a multi zone system shall require between one to ten separate electrical cable **51** to power and transmit data from the measuring instruments **21.** The electric cable **51** are routed through the inner mandrel **46** using cable feed through bypass **47** and the bypasses are sealed using compression fittings **40** above and below. .

[0035] Figure 4 illustrates a cross-sectional view of preferred downhole umbilical **14.** The umbilical **14** has capacity to house all the required control lines for the monitoring system **15.** The electrical cable **51** is used to supply electrical power and real time data transmission from the monitoring sensors **21** (See Figure 2b). The electrical cable **51** has a core conductor **53,** a core insulation **54,** a filler 57 and is constructed within a single metal tube **52.** The hydraulic line **50** is used to supply a common hydraulic pressure to each of the isolation packers **20.** The hydraulic line **50** is a single metal tube which provides a polished surface for a compression fitting. The umbilical **14** shall also comprise some form of protection **55** such as a rubber or thermoplastic to protect against downhole environments.

[0035] Figure 5 illustrates a diagrammatic view of the wellhead suspension system **70** to provide well control and umbilical suspension cap. The multi-zone downhole monitoring system exits the wellbore through a well head or flange system **13,** and a Blow Out Preventer (BOP) **60** or similar well control device is used to provide a barrier between the wellbore surface. The BOP seals around the downhole umbilical **14** and allows the umbilical to be suspended in the well by means of an umbilical clamp or hang-off plate **61** situated in a hang-off sub **62.** Preferably the hang-off plate **61** is bolted or clamped around the outer diameter of the umbilical **14** and prevents any slippage of the umbilical **14** and attached monitoring system. The wellhead suspension system also has an end cap sub **63** to allow the umbilical to be terminated to an electrical wellhead outlet **18** and provide the necessary barriers to ensure all possible leak paths from the well are sealed. A surface cable **17** is terminated to the umbilical **14** in the wellhead outlet **18.** The surface cable **17** is then tied into the surface control unit **16** for data capture and further telemetry if required.

[0036] This specification is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the manner of carrying out the disclosure. It is to be understood that the forms of the disclosure herein shown and described are to be taken as the presently preferred embodiments. As already stated, various changes may be made in the shape, size and arrangement of components or adjustments made in the steps of the method without departing from the scope of this disclosure. For example, equivalent elements may be substituted for those illustrated and described herein and certain features of the invention maybe utilized independently of the use of other features, all as would be apparent to one skilled in the art after having the benefit of this description of the disclosure.

[0037] While specific embodiments have been illustrated and described, numerous modifications are possible without departing from the spirit of the invention, and the scope of protection is only limited by the scope of the accompanying claims.

CLAIMS

What we claim is:

1. A multi-zone monitoring system allowing simultaneous measurement of separate zones of multi-zone wellbore formations comprising:
   a) a multi-component umbilical containing both electrical lines and hydraulic fluid lines;
   b) an inflatable isolation packer that can traverse through the wellbore and be inflated with hydraulic fluid to seal off a portion of the wellbore;
   c) wherein the inflatable isolation packer further comprises: one or more cable bypass feed throughs for the umbilical's electric and hydraulic fluid lines;
   d) wherein an hydraulic line of the multi-component umbilical is attached to a pump and the inflatable isolation packer with pressure testable sealed connectors and compression fittings.
2. The multi-zone monitoring system of claim 1 wherein the pressure testable sealed connectors of the inflatable isolation packer can be individually pressure tested to verify the seal integrity of the connection prior to deployment.
3. The multi-zone monitoring system of claim 1 wherein the pressure in the hydraulic line can be monitored at surface to verify that seal integrity of the hydraulic line is being maintained during the operating life of the system.
4. The multi-zone monitoring system of claim 1 further comprising an instrument to monitor temperature or pressure within the wellbore.
5. The multi-zone monitoring system of claim 1 further comprising an inflatable isolation packer dimensioned to travel through the well bore in a deflated position and seal and separate the wellbore into two or more zones when in an inflated position.
6. The multi-zone monitoring system of claim 3 wherein the inflatable isolation packer is raised and lowered through the wellbore by the umbilical.

7. The multi-zone monitoring system of claim 1 further comprising an inflatable isolation packers in the form of an inflatable, pressure sealing elastomer inflated and shaped to seal or pack-off the internal diameter of the borehole.
8. The multi-zone monitoring system of claim 1 wherein the electrical lines are routed through an inner mandrel of the inflatable isolation packer using cable feed through bypasses and the bypasses are sealed using compression fittings.
9. The multi-zone monitoring system of claim 1 wherein the seal integrity of the compression fittings on the electrical lines routed through inflatable isolation packer can be pressure tested to verify the seal integrity of the connection prior to deployment.
10. The multi-zone monitoring system of claim 1 further comprising two of more inflatable isolation packers attached to the umbilical at predetermined distances so that when lowered into the well bore and inflated, at least one geologic formation is isolated in the wellbore from other geologic formations.
11. The multi-zone monitoring system of claim 1 further comprising a plurality of inflatable isolation packers attached to the umbilical at predetermined distances so that when lowered into a well bore and inflated, a plurality of geologic formations are isolated in the well bore.
12. A multi-zone borehole monitoring system comprising:
    a) a winch;
    b) an umbilical comprising a plurality of metal jacketed tubes structured to be positioned downhole in a wellbore;
    c) at least one jacketed metal tube of the umbilical containing electrical wires;
    d) at least one jacketed metal tube of the umbilical in communication with a fluid pump;
    c) at least one inflatable isolation packer in communication with the umbilical and positionable downhole in the wellbore; and

d) electrically powered wellbore monitoring sensors positioned downhole in the wellbore in communication with the umbilical.

13. The multi-zone borehole monitoring system of claim 12 further comprising the inflatable isolation packer in communication with a jacketed metal tube of the umbilical wherein the jacketed metal tube is in communication with the fluid pump.

14. The multi-zone borehole monitoring system of claim 12 wherein the electrically powered wellbore monitoring sensors are in communication with a jacketed metal tube of the umbilical containing electrical wires.

15. The multi-zone borehole monitoring system of claim 12 further comprising at least one compression fitting.

16. The multi-zone borehole monitoring system of claim 12 further comprising the umbilical containing a reinforcing strand.

a. A multi-zone borehole monitoring system of a metal jacketed umbilical supporting at least one inflatable isolation packer and wellbore monitoring equipment comprising:

a) a pressure-testable sealed connection between the hydraulic line within the umbilical and inflatable isolation packer to provide a pressure barrier for applying fluid pressure to an inflatable isolation packer inflation port

b) electric lines within the umbilical routed through an inner mandrel of the inflatable isolation packer wherein the electric lines feed through bypasses and the umbilical and bypasses are sealed using pressure rated compression fittings; and

c) a port in the inner mandrel to verify the pressure seal integrity of the compression fittings on the electric lines prior to deployment.

17. A method of monitoring geologic formations in a wellbore comprising:

a) attaching a plurality of inflatable isolation packers at predetermined distances to an umbilical containing a hydraulic line for inflating each packer;

b) monitoring each connection of the hydraulic line to each inflatable isolation packer;

c) attaching monitoring equipment to the umbilical at predetermined distances to the umbilical;

d) lowering the monitoring equipment and inflatable isolation packers down a wellbore using the umbilical; and

e) monitoring at least one equipment connection and hydraulic line connection at a surface.

18. The method of claim 17 for monitoring geologic formations in a wellbore further comprising the step of deflating the inflation isolation packers by control from the surface, raising the inflation isolation packers and equipment utilizing the umbilical and removing the inflation isolation packers and equipment from the wellbore.

19. The method of claim 17 for monitoring geologic formations in a wellbore further comprising monitoring at least one equipment piece via the umbilical.

20. The method of claim 17 for monitoring geologic formation in a wellbore further comprising monitoring at least one equipment piece by telemetry.

21. The method of claim 17 for monitoring geologic formations in a wellbore by attaching at least one inflatable isolation packer at a predetermined distance to the umbilical so the inflatable isolation packer can be inflated in between at least two geologic formations intercepted by the wellbore.

22. The method of claim 17 for monitoring geologic formations in a wellbore by attaching at least one inflatable isolation packer at a predetermined distance to the umbilical so that the inflatable isolation packer can be inflated beneath or above at least one geologic formation intercepted by the well bore.

23. A method of claim 17 for monitoring geologic formations in a wellbore further comprising a wellhead suspension system to provide well control and umbilical suspension cap wherein the multi-zone downhole monitoring system exiting the wellbore through a well head or flange system and

using a Blow Out Preventer (BOP) or similar well control device to provide a barrier between the wellbore and the surface and the well control device seals around the umbilical and allowing the umbilical to be suspended in the well by means of an umbilical clamp or hang-off plate situated in a hang-off sub.

24. The method of claim 23 for monitoring geologic formations further comprising bolting or clamping the hang-off plate around the outer diameter of the umbilical.

25. The method of claim 17 for monitoring geologic formations further comprising attaching monitoring equipment to the umbilical at predetermined distances to the umbilical further comprising placing the monitoring equipment proximate to at least one geologic formation intersected by the wellbore.

26. A method of deflating an inflatable isolation packer comprising cutting or piercing a bladder of the inflatable isolation packer to discharge the inflating fluid causing the inflatable isolation packer to deflate.

27. The method of claim 26 of deflating an inflatable isolation packer further comprising cutting or piercing the bladder under a determined applied load.

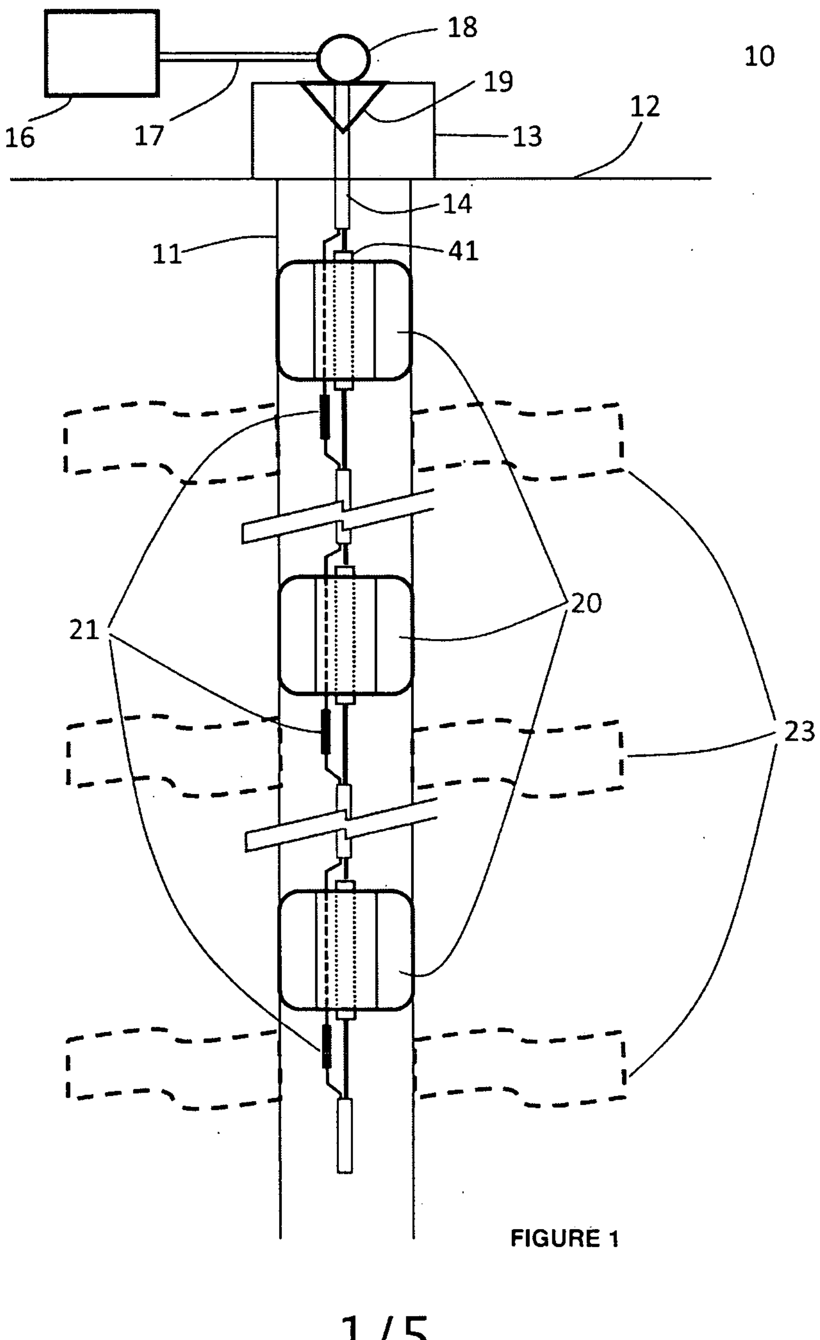

FIGURE 1

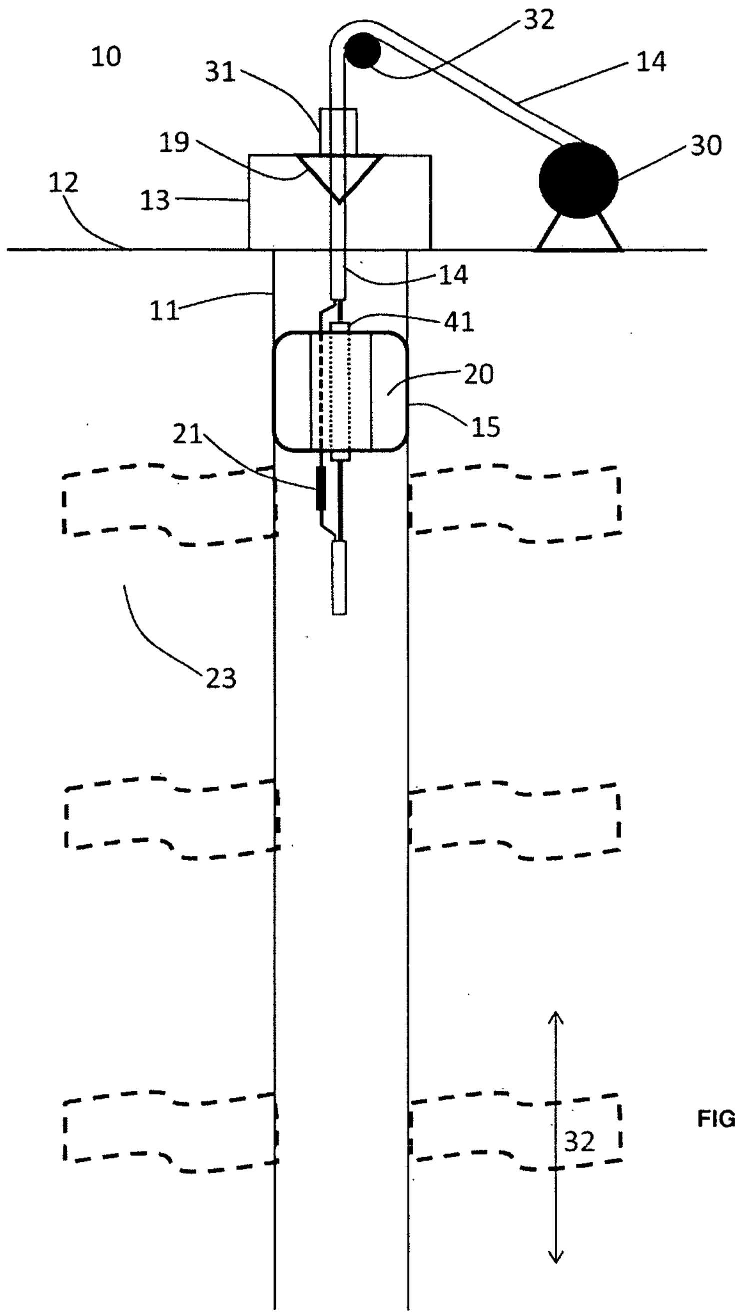

FIGURE 2a

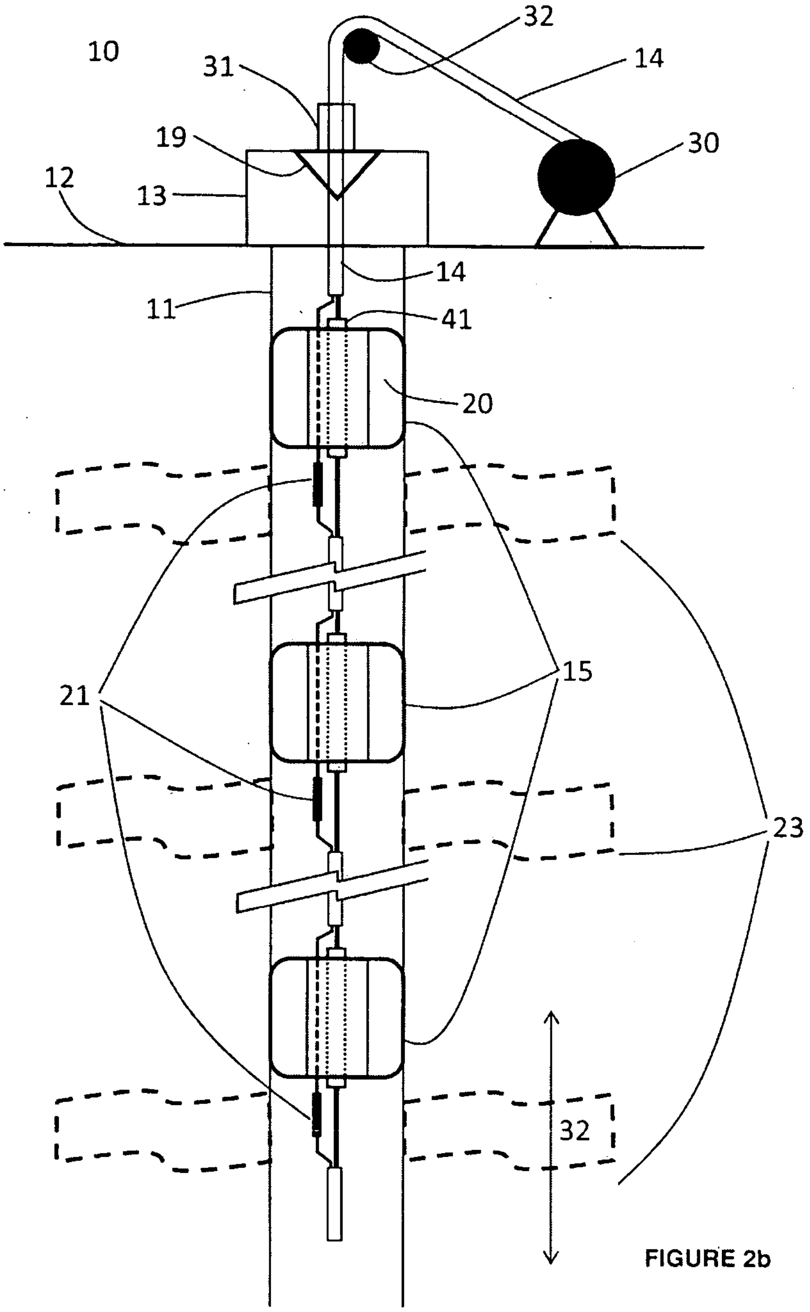

FIGURE 2b

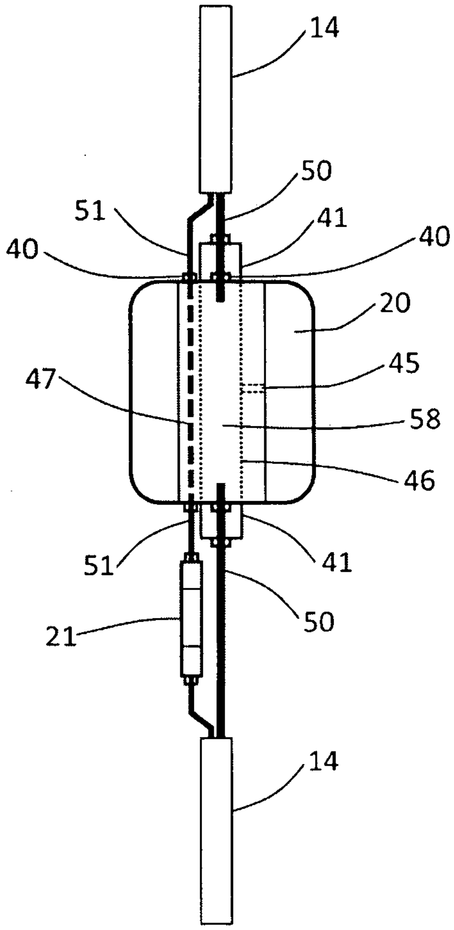

FIGURE 3

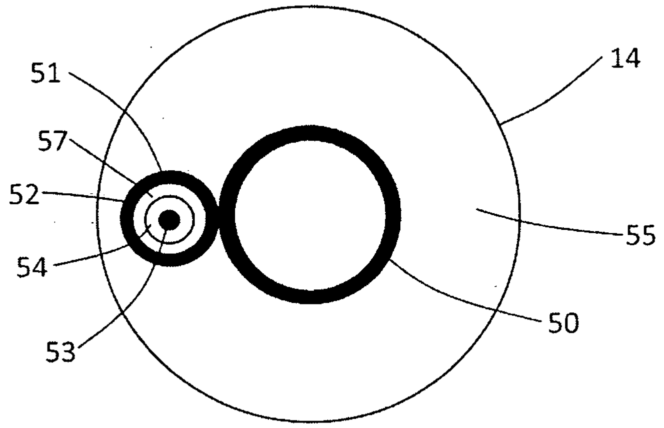

FIGURE 4

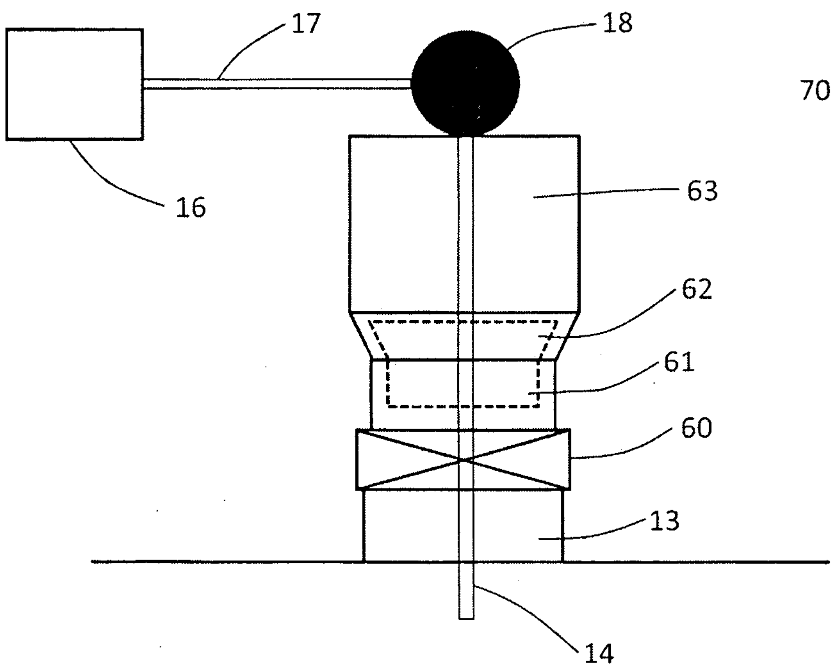

FIGURE 5