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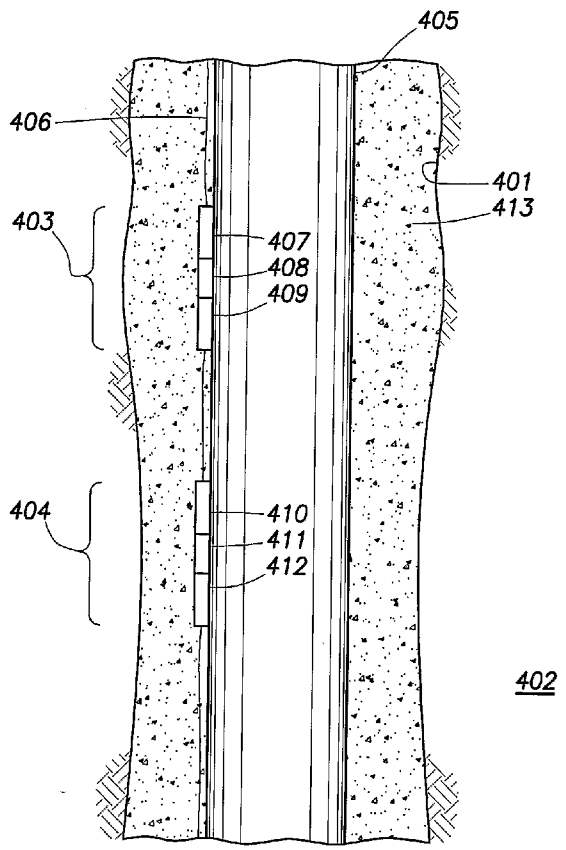
(54) Title: MONITORING FORMATION PROPERTIES



(57) Abstract: A method for monitoring pressure in a formation traversed by at least one wellbore comprising providing a tubular element having an outside surface, attaching a perforating gun oriented in such a way that when fired, the perforating gun does not damage the tubular element, connecting a sensor to the perforating gun in close proximity to the perforating gun wherein the sensor is exposed to the wellbore, inserting the tubular element into the wellbore, securing the tubular element in the wellbore, firing the perforating gun to penetrate the formation, exposing the sensor to the formation pressure, and monitoring the pressure in the formation with the sensor to obtain pressure data.

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MONITORING FORMATION PROPERTIES

Field of Invention

The present invention relates to a method and apparatus for monitoring properties in a formation traversed by at least one wellbore.

Background

In the oil and gas industry, the sampling of fluids and measuring formation pressure in the porous strata of the formation being drilled can provide valuable information about the formation and its ability to yield oil and/or gas. Formation pressure is one of the key properties that engineers, geologists, and petrophysicists use to characterize the mobility of oil and gas formations and estimate reserves. Formation pressure data can be collected at specific times throughout the life of the well or it can be monitored on a long-term basis. Ideally, operators would like to be able to obtain a real time pressure profile of the well over its lifetime to aid in optimization of production.

Formation pressures can be measured using a variety of methods. The most common method involves running a wireline formation pressure tester (FPT) in either an open or cased hole completion. This method requires drilling into the formation or shooting a hole in the casing. The FPT method works well in permeable formations; however, it is limited to one data point for pressure at a specified time. Obtaining multiple data points is desirable because it is difficult to determine whether a pressure measurement reflects the virgin formation pressure or pressure after depletion. In addition, having a number of measurements over an extended period of time allows for identification of depletion even if the actual virgin formation pressure is unknown.

In tighter, less permeable formations, the traditional FPT method has limits because it takes a long time to build up to the formation pressure. In addition, the method is less accurate in formations prone to a phenomenon known as supercharging. Supercharging is the increase of formation pressure around the wellbore as a result of exposure to the higher pressure from the mud used in the drilling process. In supercharged reservoirs, the mudcake fails to adequately hold the drilling fluid in the wellbore, causing drilling fluid to penetrate the formation and create a high-pressure or "super-charged" zone. Using the FPT method under these conditions may require extrapolation or yield an inaccurate data point for pressure that is between the mud pressure and the formation pressure.

Another method used in tighter formations is the diagnostic formation injection test (DFIT). In this method, the formation is pressured up, a fracture is created beyond the supercharged area and the pressure fall off back to the formation pressure is monitored. Usually pressure is measured at the surface and the accuracy is within hundredths of psi. A gauge may also be placed downhole to obtain a more accurate measurement; however, in tight formations, it is still a challenge to get an accurate measurement within 100 psi.

Long-term build-up is another method for measuring formation pressure. Here the well is shut in for an extended period (weeks or months) and the pressure is measured as it builds back up to the current formation pressure. As with the DFIT method, measuring can be performed at the surface or downhole, but both methods require that the well be shut in with no production. The long-term build-up method traditionally yields one data point representing the pressure for the whole well. In principle, a profile could be obtained by placing a number of gauges between bridge plugs in the casing, but doing so may force the operator to abandon the well or rely on retrievable bridge plugs. The long-term build-up method will also likely damage the casing integrity because the casing has to be perforated in order to have communication between the gauge and the formation.

US Patent 5,467,823 discloses a method and apparatus of monitoring subsurface formations containing at least one fluid reservoir and traversed by at least one well. The method includes lowering a sensor to a depth level corresponding to the reservoir, positioning the sensor at this depth while isolating the section of the well where the sensor is located from the rest of the well and providing fluid communication between the sensor and the reservoir. Because this system requires isolating the section of the well where the sensor is located from the rest of the well, this could not serve as a long-term pressure measurement option. In addition, the chances of maintaining pressure isolation while achieving communication to surface over the wireline with multiple sensors are remote.

Summary of the Invention

The present inventions include a method for monitoring pressure in a formation traversed by at least one wellbore comprising providing a tubular element having an outside surface, attaching a perforating gun oriented in such a way that when fired, the perforating gun does not damage the tubular element, connecting a sensor to the perforating gun in close proximity to the perforating gun wherein the sensor is exposed to the wellbore, inserting the tubular element into the wellbore, securing the tubular element in the wellbore, firing the perforating gun to penetrate the formation, exposing the sensor to the formation pressure, and monitoring the pressure in the formation with the sensor to obtain pressure data.

The present inventions also include an apparatus for monitoring pressure in a formation traversed by at least one wellbore lined with casing comprising a wireless communications module mounted on the outside of the casing, a perforating gun oriented away from the casing mounted on the outside of the casing, and a sensor mounted on the outside of the casing wherein the sensor is not protected from overpressure.

The present inventions also include an apparatus for monitoring pressure in a formation traversed by at least one wellbore comprising a tubular element having an outside surface, a wireless communications module mounted on the outside surface of the tubular element, a perforating gun oriented away from the tubular element mounted on the outside surface of the tubular element, and a sensor mounted on the outside surface of the tubular element wherein the sensor is not protected from overpressure.

Brief Description of the Drawings

The present invention is better understood by reading the following description of non-limitative embodiments with reference to the attached drawings, wherein like parts of each of the figures are identified by the same reference characters, and which are briefly described as follows:

Figure 1 illustrates a perspective view of one embodiment of the pressure monitoring apparatus.

Figure 2 illustrates a side view of one embodiment of the pressure monitoring apparatus installed in a wellbore.

Figure 3 shows a top view of the wellbore illustrating the direction of the perforations.

Figure 4 illustrates a side view of another embodiment of the pressure monitoring apparatus installed in a wellbore.

Detailed Description of the Invention

Figure 1 shows one embodiment of an apparatus for monitoring formation properties. In this embodiment, tubular element 101 is a section of casing, liner, or other material used to maintain the integrity of the wellbore. Tubular element 101 may also be a section of tubing, cement stinger, or other device used to lower equipment into a wellbore. Perforating gun 102 and sensor 103 are mounted on the outside of tubular element 101 in close proximity to one another. Perforating gun 102 and sensor 103 may be connected either directly or via additional tubulars or hoses.

Any type of perforating gun may be used; however the direction of the perforations must point away from the casing (tubular element 101) so that when fired, the perforating gun does not damage the casing. In a wireless embodiment of the invention, perforation gun 102 may be fired by pressuring up the casing using conventional methods of wireless perforating. In an alternative embodiment, a wire may be attached to perforating gun 102 and used for firing. In this embodiment, a conventional casing conveyed wireless perforating gun with the inward facing shaped charges removed is shown.

Any type of sensor may be used including, for example, strain gauges, quartz gages, and other conventional sensing devices. The embodiments in this application discuss using a pressure sensor; however, sensors that measure other well properties could be employed.

Wireless communications module 104 is shown connected to tubular element 101. Wireless telemetry technology is known in the industry and may be used to transmit data gathered downhole to surface production facilities. In this case, wireless communications module 104 transmits the pressure data gathered from sensor 103 real time to the surface.

Figure 2 depicts the apparatus shown in Figure 1 installed in wellbore 201. A section of wellbore 201 is shown traversing formation 202 with tubular element 101 lowered inside. As in Figure 1, perforating gun 102, sensor 103, and wireless communications module 104 are mounted on the outside of tubular element 101. In Figure 2 only one section of the wellbore is shown. Because the transmission system is wireless, an operator may install numerous sensors and perforating guns in a single wellbore to obtain the desired data.

In operation, once tubular element 103 is lowered to its desired position in wellbore 201, cement 203 is optionally pumped through annulus 204, securing tubular element 101 in place. Then the casing is pressured up and perforating gun 102 is activated. Figure 3 depicts the top view of the apparatus in the wellbore to indicate the direction of the perforations. Shape charges 301 are shown connected to perforating gun 102. When fired, shaped charges 301 penetrate cement 203 and formation 202 according to paths 302 thereby exposing sensor 103 to the formation pressure. During the perforating operation, tubular element 101 remains intact and sensor 103 is not damaged even though it is in direct pressure communication with the gun and not protected from the pressure shock generated by the firing of the gun (referred to as "overpressure" in the industry). Sensor 103 gathers data, which is transmitted to surface unit 205 by wireless communication module 104, thus providing pressure data without the need to drill a dedicated observation well or compromise casing integrity.

Another embodiment of the invention uses a hard-wired connection to transmit the pressure data gathered downhole. Figure 4 depicts a hard-wired embodiment that is installed on the outside of a section of casing. Wellbore 401 is shown traversing formation 402. First apparatus 403 and second apparatus 404 are shown mounted on the outside of casing 405. First apparatus 403 and second apparatus 404 are connected by wire 406, which extends to the surface (not shown). First apparatus 403 and second apparatus 404 consist of perforating guns (407 and 410), sensors (408 and 411), and communications modules (409 and 412). The entire apparatus is secured in the wellbore using cement 413. In this embodiment, the data collected by sensors 408 and 411 is transmitted using wire 406 to the surface (not shown). Transmission with a wire may be less reliable than using wireless communication because the wire might be damaged during placement in the hole or when zones are perforated for production. However, hard-wired transmission systems are advantageous because they provide higher frequency data, can transmit data for longer periods, and enable deeper measurements to be contained. Furthermore the wire may also be used to fire the perforating guns.

Although the system of some embodiments of the present invention was developed for tight, low permeability reservoirs, some embodiments of the invention may also be useful in high permeability reservoirs. In many areas, multiple reservoirs penetrated by a single wellbore are produced and managed separately because of legal or reservoir management requirements. Some embodiments of the present invention enable the operator to have a single well produce one horizon, while acting as a pressure observation well for one or more other reservoirs, thus obviating the need to drill dedicated pressure observers.

Advantages of the embodiments of the invention include one or more of the following:

(i) Provides accurate pressure measurement in tight low permeability formations

(ii) Maintains casing integrity

(iii) Allows for simultaneous production and monitoring
(iv) Avoids need to drill separate observation well
(v) May be used in high permeability formations in which multiple reservoirs are penetrated by single wellbore
(vi) Uses multiple bullets, improving the chance of establishing pressure communication with formation.

Those of skill in the art will appreciate that many modifications and variations are possible in terms of the disclosed embodiments, configurations, materials, and methods without departing from their spirit and scope. Accordingly, the scope of the claims appended hereafter and their functional equivalents should not be limited by particular embodiments described and illustrated herein, as these are merely exemplary in nature.

CLAIM

1. A method for monitoring pressure in a formation traversed by at least one wellbore comprising:

providing a tubular element having an outside surface;

attaching a perforating gun oriented in such a way that when fired, the perforating gun does not damage the tubular element;

connecting a sensor to the perforating gun in close proximity to the perforating gun wherein the sensor is exposed to the wellbore;

inserting the tubular element into the wellbore;

securing the tubular element in the wellbore;

firing the perforating gun to penetrate the formation;

exposing the sensor to the formation pressure; and

monitoring the pressure in the formation with the sensor to obtain pressure data.

2. The method of claim 1 further comprising attaching a wireless communications module to the outside of the tubular element.

3. The method of claim 2 wherein the tubular element is casing.

4. The method of claim 3 wherein the securing is performed by cementing the casing against the formation

5. The method of claim 4 wherein the firing is performed by pressuring up the casing to detonate a plurality of shaped charges.

6. The method of claim 5 further comprising transmitting the pressure data to a surface control unit using the wireless communications module.

7. The method of claim 6 further comprising producing oil from the formation.

8. The method of claim 1 further comprising connecting the sensor to a surface control unit using a hard wire connection.

9. The method of claim 8 wherein the inserting is performed by a cement stinger.

10. The method of claim 9 further comprising producing oil from the formation.

11. The method of claim 8 wherein the inserting is performed by tubing.

12. The method of claim 11 further comprising producing oil from the formation.

13. An apparatus for monitoring pressure in a formation traversed by at least one wellbore lined with casing comprising:

a wireless communications module mounted on the outside of the casing;

a perforating gun oriented away from the casing mounted on the outside of the casing; and

a sensor mounted on the outside of the casing wherein the sensor is not protected from overpressure.

14. The apparatus of claim 13 further comprising a surface control unit, which is operatively connected to the wireless communications module.

15. The apparatus of claim 14 wherein the sensor is a pressure gauge.

16. An apparatus for monitoring pressure in a formation traversed by at least one wellbore comprising:

a tubular element having an outside surface;

a wireless communications module mounted on the outside surface of the tubular element;

a perforating gun oriented away from the tubular element mounted on the outside surface of the tubular element; and

a sensor mounted on the outside surface of the tubular element wherein the sensor is not protected from overpressure.

17. The apparatus of claim 16 further comprising a deployment device selected from the group consisting of tubing, cement stingers, and wireline.

18. The apparatus of claim 17 further comprising a surface control unit which is operatively is connected to the wireless communications module.

19. The apparatus of claim 18 wherein the sensor is a pressure gauge.

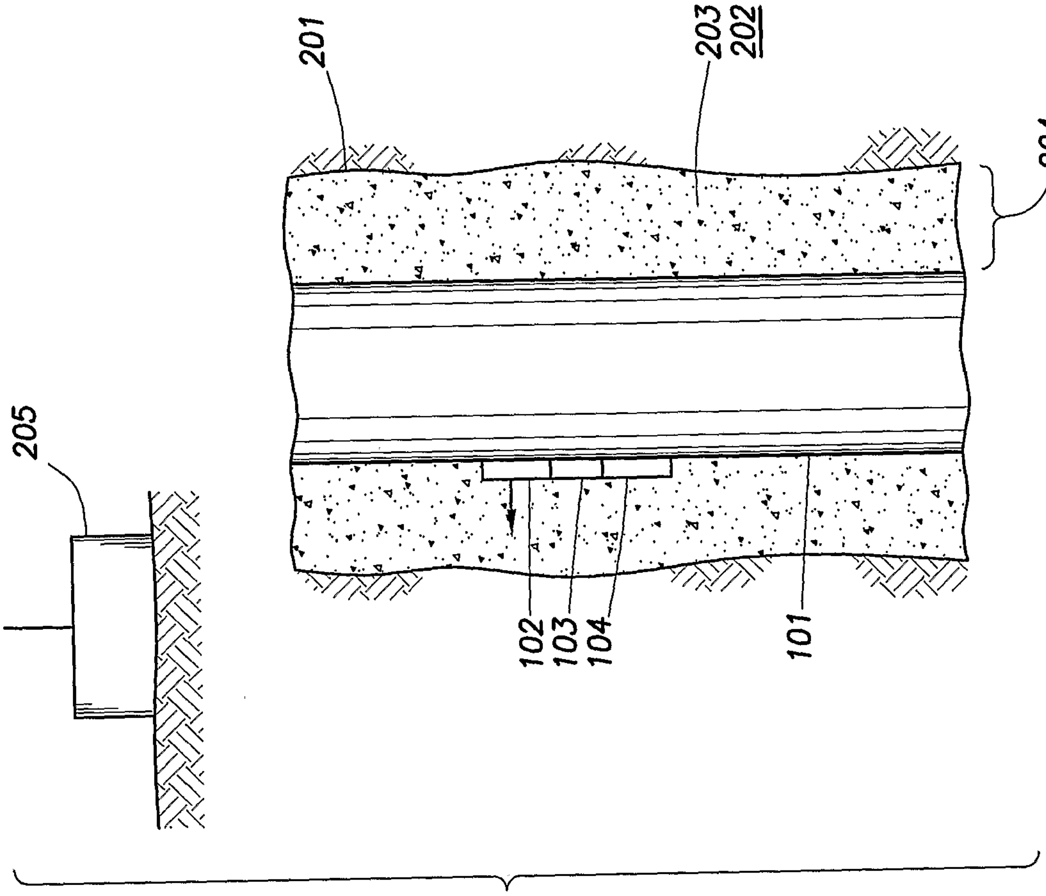

FIG.2

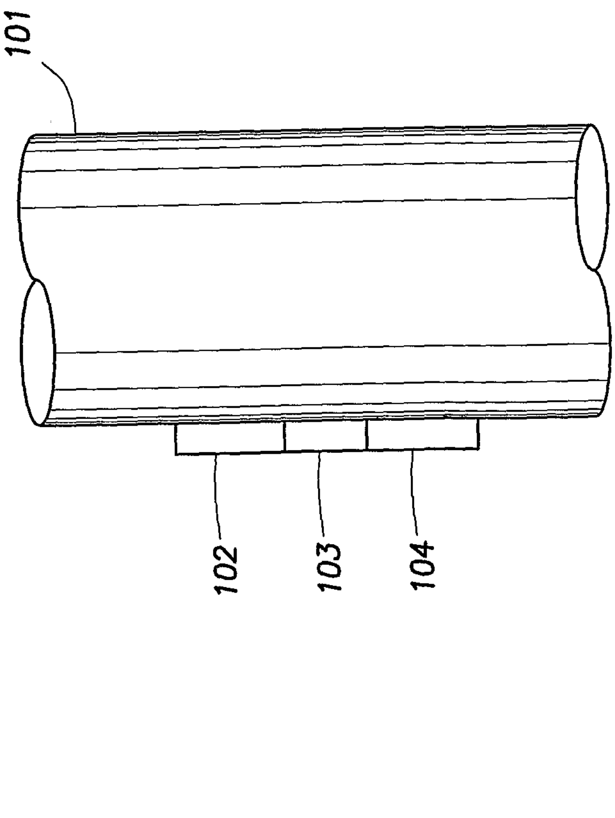

FIG.1

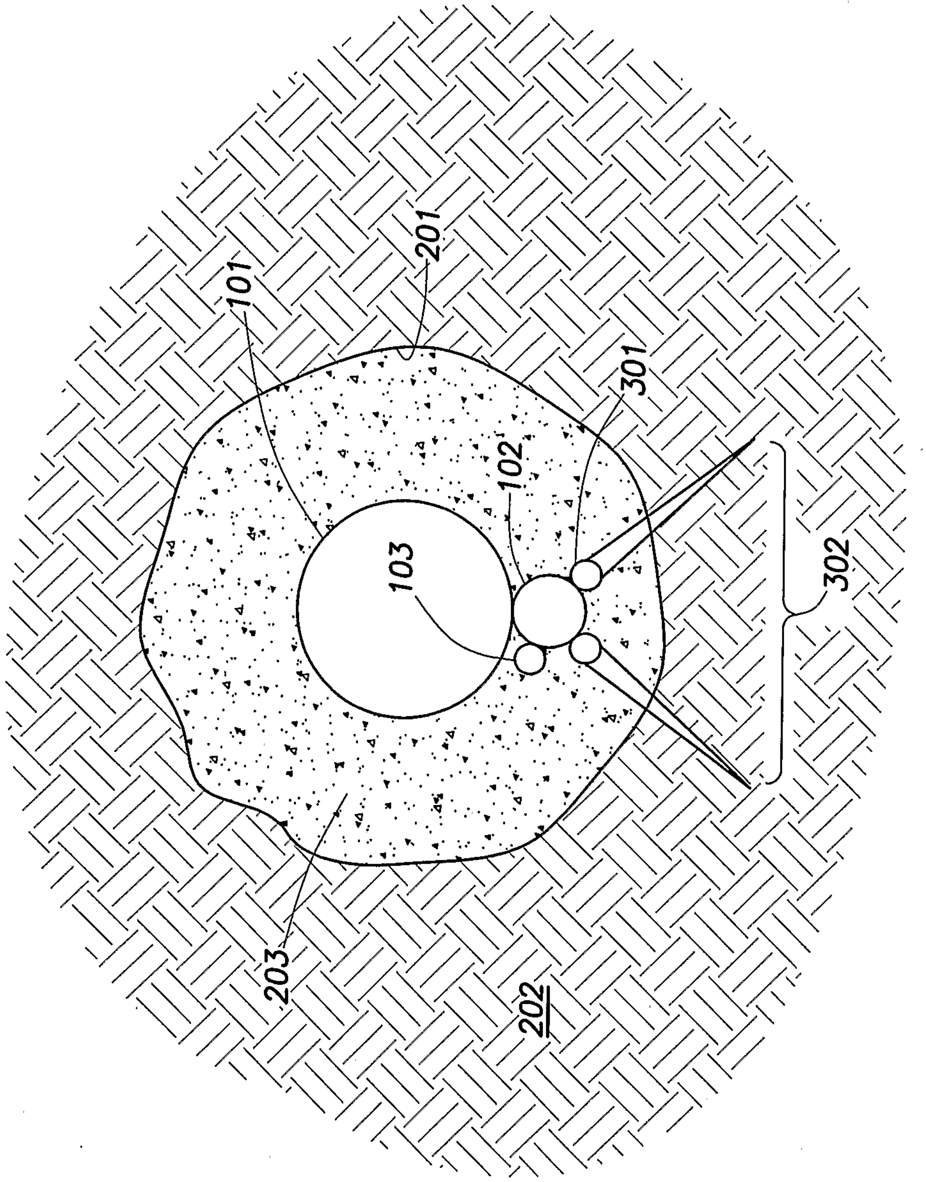

FIG.3

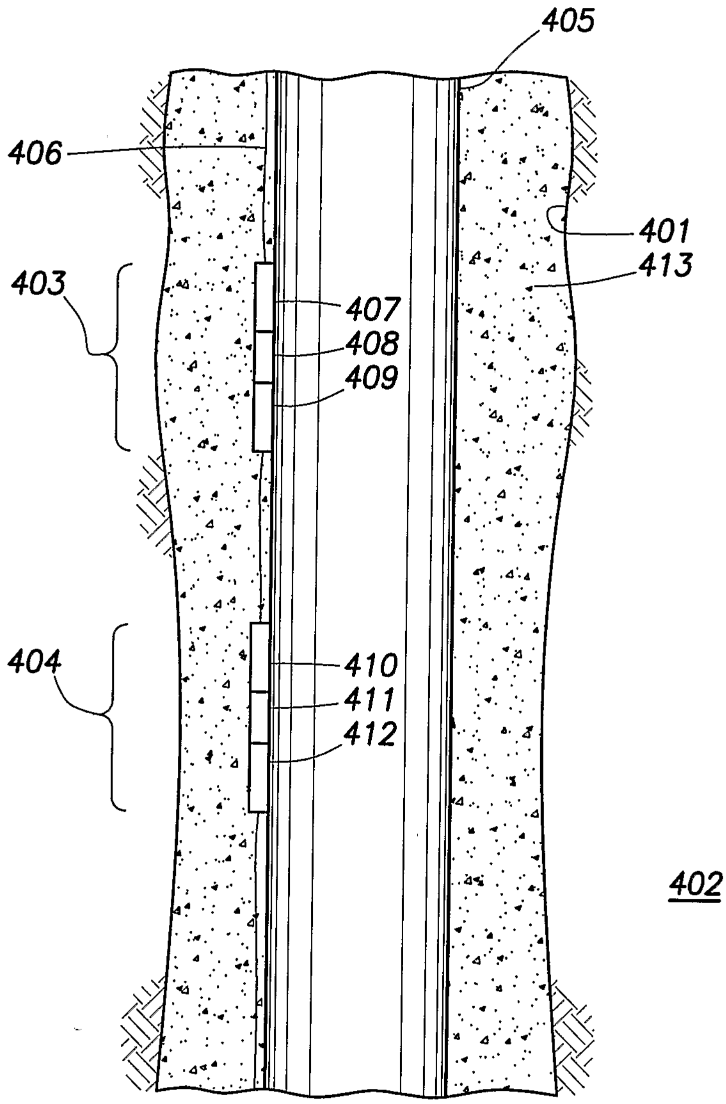

FIG.4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/042924

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B41/00 E21B43/116 E21B43/119 E21B47/01 E21B47/06 E21B47/12

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 practical, search terms used)

EPO-Internal

C. 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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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
16 March 2007	28/03/2007

Name and mailing address of the ISA/	Authorized officer
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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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