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— as to applicant's entitlement to apply for and be granted a
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[Continued on next page]

(54) Title: WELLBORE SYSTEMS WITH HYDROCARBON LEAK DETECTION APPARATUS AND METHODS

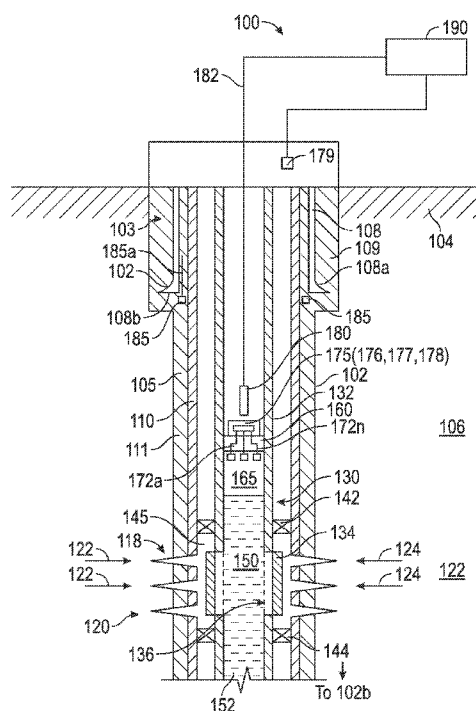


FIG. 1

(57) Abstract: In one aspect, a wellbore system is disclosed that in one non-limiting embodiment includes a cement section in the wellbore formed to prevent flow of fluids including hydrocarbons through the cement section, a plug disposed uphole of the cement section to provide a space between the cement section and the plug and a sensor in the space for providing measurements relating to a parameter of interest. In one aspect, the parameter of interest may include one or more of presence and extent of a hydrocarbon, presence of moisture; pressure; and temperature. The system may further include a transmitter that transmits measurements from the sensor via a communication line or wirelessly to a receiver for processing the sensor measurements.



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WELLBORE SYSTEMS WITH HYDROCARBON LEAK DETECTION APPARATUS AND METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Application No. 14/278236, filed on May 15, 2014, which is incorporated herein by reference in its entirety.

BACKGROUND

1. Field of the Disclosure

[0001] This disclosure relates generally to apparatus and methods for determining integrity of cement sections in wellbores.

2. Background of the Art

[0002] Wellbores are drilled in subsurface formations for the production of hydrocarbons (oil and gas). Modern wells can be drilled to great well depths, often more than 15,000 ft. Hydrocarbons are trapped in various traps or zones in the subsurface formations at different wellbore depths. Such zones are referred to as reservoirs or hydrocarbon-bearing formations or production zones. A casing is generally placed inside the wellbore and the space between the casing and the wellbore (annulus) is filled with cement. A production string or assembly containing a number of devices is placed inside the casing to perform a variety of operations downhole, including, but not limited to, fracturing, treatment and production of fluids from the formation to the surface. Once the well is no longer productive, a section of the well is filled or plugged with cement and abandoned. In some other cases, plugs made of other materials may be placed in the well prior to abandoning the well. It is important to determine the integrity of the cement plug or other plugs prior to abandoning the well. Pressure tests are commonly performed to determine the integrity of the cement and other plugs. Such methods, however, do not provide long term information about the ongoing integrity of the cement plugs.

[0003] The disclosure herein provides apparatus and method for detecting leaks, such as of hydrocarbons, through the cement and other plugs to provide ongoing information about the integrity of the cement and other plugs.

SUMMARY

[0004] In one aspect, a wellbore system is disclosed that in one non-limiting embodiment includes a plug in the wellbore formed to prevent flow of fluids therethrough,

including hydrocarbons, a seal disposed uphole of the cement section to provide a space between the plug and the seal and a sensor in the space for providing measurements relating to a parameter of interest. In one aspect, the parameter of interest may include one or more of: presence and extent of a hydrocarbon in the space; presence of moisture in the space; pressure; and temperature. The system may further include a transmitter that transmits measurements from the sensors via a communication link or wirelessly to a receiver for processing the sensor measurements.

[0005] In another aspect, a method of determining integrity of a plug or a cement section disposed in a wellbore is disclosed. The method, in one non-limiting embodiment includes: creating a sealed space uphole of the plug or the cement section; and placing a sensor in the space for providing measurements relating to a property of interest relating to the integrity of the plug or the cement section. The parameter of interest may be any suitable parameter including, but not limited to, presence and extent of a hydrocarbon in the space, moisture in the space, pressure, and temperature.

[0006] Examples of the more important features of the apparatus and methods disclosed herein are summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features that will be described hereinafter and which will form the subject of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For a detailed understanding of the apparatus and methods disclosed herein, reference should be made to the accompanying drawings and the detailed description thereof, wherein like elements are generally given same numerals and wherein:

FIG. 1 shows a wellbore system that includes a sensor for detecting a parameter of interest in a space between a cement section or a plug and a seal or a second plug uphole of the cement section or the plug, according to one non-limiting embodiment of the disclosure; and

FIG. 2 shows a wellbore system without a production string in which sensors are placed in a space between a cement section and a plug in a manner shown in FIG. 1.

DETAILED DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 shows a wellbore system 100 that includes a wellbore 102 formed from a surface location 104 into a formation 106. An upper casing 108 placed in the wellbore

extends to a first depth 102a and a lower casing 110 that runs from proximate the end 108a of the casing 108 to the bottom 102b of the wellbore. Cement 109 fills the annulus 103 between the casing 108 and the wellbore 102, while cement 111 fills the annulus 105 between the casing 110 and the wellbore 102. Perforations 118 through the casing 110 and the cement 111 at a production zone 120 allow formation fluid 122, including hydrocarbons, to flow from the formation 106 into the casing 110, as shown by arrows 124. A production string 130 is shown placed or deployed inside the casing 110 to produce the formation fluid 122 to the surface.

[0009] The production string 130 typically includes a tubular 132, one or more sand screens, such as screen 134, openings 136 in the tubular 132 and various other devices, such as valves (not shown), to transport the formation fluid 122 from the production zone 120 to the surface. Isolation devices, such as packers 142 and 144 to seal the annulus 145 between the casing 108 and the production string 130 above and below the production zone 120. Once the well 102 has lived its useful production life or for other reasons, it may be desirable to abandon the well. In such a case, in one non-limiting embodiment, a section 150 of the production string 130 may be filled with cement 152 (also referred to herein as the “cement plug”) so as to prevent the formation fluid 122 from entering into the production tubing 132.

[0010] Still referring to FIG. 1, to provide information about the integrity of the cement section 150 over a relatively long time period, in one non-limiting embodiment, a seal, such as a plug 160 may be installed a certain distance above (uphole) of the cement section 150 to provide a space 165 (which may be a sealed space) between the cement section 150 and the plug 160. One or more sensors, such as sensors 170a, 170b through 170n may be placed in the space 165 to provide measurements (information, data, signals etc.) relating to one or more parameters of interest. The parameters of interest may include, but are not limited to, presence and extent of a chemical, such as a hydrocarbon, moisture (water), pressure and temperature. The sensors 172a-172n may include, but are not limited to, a chemical sensor that provides measurements relating to a chemical, such as a hydrocarbon, a moisture sensor, a pressure sensor and a temperature sensor.

[0011] Still referring to FIG. 1, in one embodiment, one or more of the sensors 170a-170n may be attached to the seal 160 so that such sensors are exposed to the space 165. Communication links (electrical conductors, optical fibers, etc.) 172a-172n respectively for sensors 170a-170n, may be run through the seal 160 to a circuit 175 above (uphole) of the seal 160 or may be integral to the seal 160. The circuit 175, in one non-limiting embodiment, may include a conditioning circuit 176 to preprocess the signal received from the sensors 170a-170n and may include a controller (such as a microprocessor) 177 to process the signals

from the circuit 176 or the sensors to provide the measurements of the parameters of interest in accordance with the instructions (programs) stored in a storage device 178. The storage device may also store the sensor measurements and/or parameter of interest determined by the controller 177 for later retrieval or transmission to another device or location. In another aspect, the circuit 175 may include a transmitter 179a for transmitting the sensor measurements and/or the parameters of interest or any other desired information to a remote receiver, such as receiver 179b at or near the surface 104. In one aspect, the transmitter 179a may be an acoustic transmitter that transmits signals to a remote receiver through a fluid 123 above the plug 160 or transmits signals via another suitable wireless telemetry method. In one embodiment, the circuit 175 may be programmed to wake-up or activate a sensor to obtain measurements and transmit such information to the surface periodically or when such measurements do not meet a criterion. . In another embodiment, the circuit 175 may be programmed to transmit sensor information periodically. In another embodiment, a receiver 180 may be conveyed into the wellbore 102 on a conveying member 182, such as a wire line, slick line or coiled tubing to retrieve the information from the circuit 175. In one aspect, the receiver may wake-up or activate the circuit 179 to wirelessly receive the information from the circuit 175 or by making an electrical connection with the circuit 175. Any other known method and apparatus may also be utilized to retrieve the sensor information. A controller 190 at the surface may be provided to process sensor measurements received at the surface and to control one or more operation of the sensors 170a-170n and the circuit 175.

[0012] Still referring to FIG. 1, in another non-limiting embodiment, one or more sensors 185 may be deployed at one or more locations in an annulus, such as annulus 103 and/or 105 or at another location that may be prone to leaks. In one aspect sensors 185 may be placed in the annulus 103 during or before deployment of the casing 110 and before cementing the annulus 103. Sensors 185 may be placed in a container with the sensors exposed to their surrounding for making measurements. The sensors 185 may include a circuit, such as circuit 175 that wirelessly transmitter signals to the surface receiver 179b. Alternatively, communication lines 185a may be run from the sensors 185 to a surface controller 190 or to a remote station for remotely monitoring the parameters of interest. Such sensors may also be placed at any other location in the wellbore for monitoring the parameters of interest over a time period. In aspects, power to the sensors 170a-170n, 185 and circuit 175 may be provided with batteries placed in the circuits, which batteries may be rechargeable by a conveying member, such as member 182. In another embodiment, instead of filling the cement, a plug made from a suitable material, such as an elastomeric material,

may be placed in the wellbore to seal an area below such a plug. In such cases, the plug 160 may be disposed uphole of such a seal to detect the presence of a parameter of interest relating to the integrity of such plug, in the manner described above in relation to the cement section. In other embodiment, the plug 160 may not provide a sealed space, but the sensor 150 still may provide measurements of a parameter of interest relating to the integrity of the cement plug or such other plug.

[0013] FIG. 2 shows a wellbore system 200 that does not include a production string, such as string 160 shown in FIG. 1. Referring to FIGS. 1 and 2, the wellbore system 200 is shown to include a casing 210 with perforations 218 at a production zone 220. In such a well system, a cement section 250 may be provided in the casing to prevent a formation fluid 222 from flowing from 220 into the casing 210. A seal or plug 260 containing sensors 170a-170n and circuit 175 may be deployed above the cement section 250 with the sensors exposed to a space between the cement section 250 and the seal 260. The sensor information may be obtained and processed in the manner described in reference to FIG. 1.

[0014] The foregoing disclosure is directed to certain exemplary embodiments and methods. Various modifications will be apparent to those skilled in the art. It is intended that all such modifications within the scope of the appended claims be embraced by the foregoing disclosure. The words "comprising" and "comprises" as used in the claims are to be interpreted to mean "including but not limited to". Also, the abstract is not to be used to limit the scope of the claims.

CLAIMS

1. A wellbore system, comprising:
a cement section in the wellbore to prevent flow of fluids including hydrocarbons through the cement section;
a plug disposed uphole of the cement section to provide a space between the cement section and the plug; and
a sensor in the space for providing measurements relating to a parameter of interest.
2. The wellbore system of claim 1, wherein the parameter of interest is selected from a group consisting of: presence of a hydrocarbon; presence of water; pressure; and temperature.
3. The wellbore system of claim 1 further comprising a receiver for receiving signals relating to the sensor measurements.
4. The wellbore system of claim 3, wherein the receiver receives signals via one of: a wire; an optical fiber; and a wireless device.
5. The wellbore system of claim 3 further comprising a processor for determining the parameter of interest from one of the sensor measurements and the signals from the sensor.
6. The wellbore system of claim 1, wherein the sensor is selected from a group consisting of a: chemical sensor; water detection sensor; pressure sensor; and temperature sensor.
7. The wellbore system of claim 1, wherein the sensor is permanently installed in the wellbore for providing the measurements relating to the parameter of interest.
8. The wellbore system of claim 3, further comprising a transmitter that transmits signals to one of: a receiver on a conduit conveyed into the wellbore; and wirelessly to a receiver at spaced from the transmitter.
9. A wellbore system comprising:
a wellbore formed in a formation;
a casing in the wellbore and a cement section between the casing a wellbore wall;
a sensor in the cement section proximate to an end of the casing that provides measurements relating to a leak through the cement; and
a processor that processes the measurement from the sensor to determine presence of the leak.

10. The wellbore system of claim 9, wherein the sensor is selected from a group consisting of: a chemical sensor that provides measurements relating to a hydrocarbon; and a sensor that provides measurements relating to presence of water.

11. The wellbore system of claim 9 wherein the sensor provides measurements to the processor via one of: a wire; an optical fiber; and via a wireless transmitter.

12. A method of determining integrity of a cement section formed in a wellbore, the method comprising:

placing a plug uphole of the cement section to provide a space between the cement section and the plug; and

placing a sensor in the space for providing measurements relating to a property of interest relating to a leak through the cement section.

13. The method of claim 12, wherein the parameter of interest is selected from a group consisting of: presence of a hydrocarbon; presence of water; pressure; and temperature.

14. The method of claim 12 further comprising receiving the signals from the sensor by a receiver that is located at one of: at the surface; and in the wellbore.

15. The method of claim 14, wherein receiving the signals from the sensor comprises receiving the signals by one of: a wire; an optical fiber; and a wireless transmitter.

16. The wellbore system of claim 14 further comprising a processor for determining the parameter of interest from the measurements transmitted by the transmission.

17. The method of claim 12, wherein the sensor is selected from a group consisting of a: chemical sensor; water detection sensor; pressure sensor; and temperature sensor.

18. The method of claim 12, wherein placing the sensor in the space comprises placing the sensor permanently in the sealed space.

19. A method of detecting a leak in cement section in a wellbore, the method comprising:

placing a sensor that provides measurements relating a hydrocarbon or water proximate an end of a casing in the wellbore before cementing the cement section; and

determining from the sensor measurements presence of a leak of a hydrocarbon or water from the formation to the casing.

20. The method of claim 19, wherein the sensor is selected from a group consisting of: a chemical sensor that provides measurements for a hydrocarbon; and a sensor that provides measurements for water.

21. The wellbore system of claim 19, wherein the sensor provides measurement to a processor via one of: a wire; an optical fiber; and via a wireless transmitter.

22. A wellbore system, comprising:
a first plug to seal a section of the wellbore to prevent flow of fluids including hydrocarbons through the first plug;
a second plug uphole of the first plug to provide a space between the first plug and the second plug;
a sensor in the space for providing measurements relating to a parameter of interest relating to integrity of the first plug.

23. The apparatus of claim 22, wherein the first plug includes one of: cement; and an elastomeric material.

24. The apparatus of claim 23 further comprising a processor that processes measurements from the sensor to provide a measure of a leak of a hydrocarbon through the first plug.

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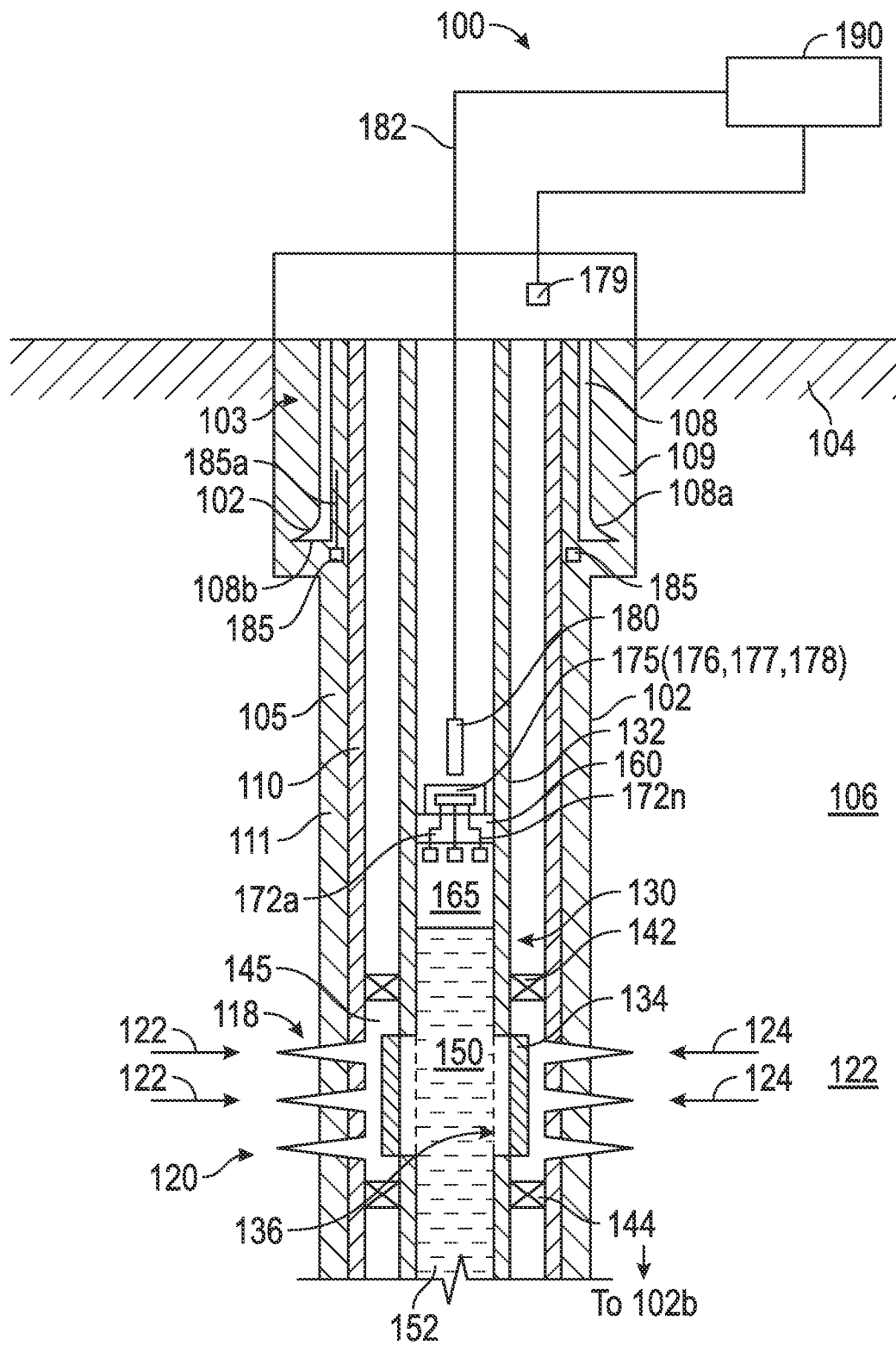


FIG. 1

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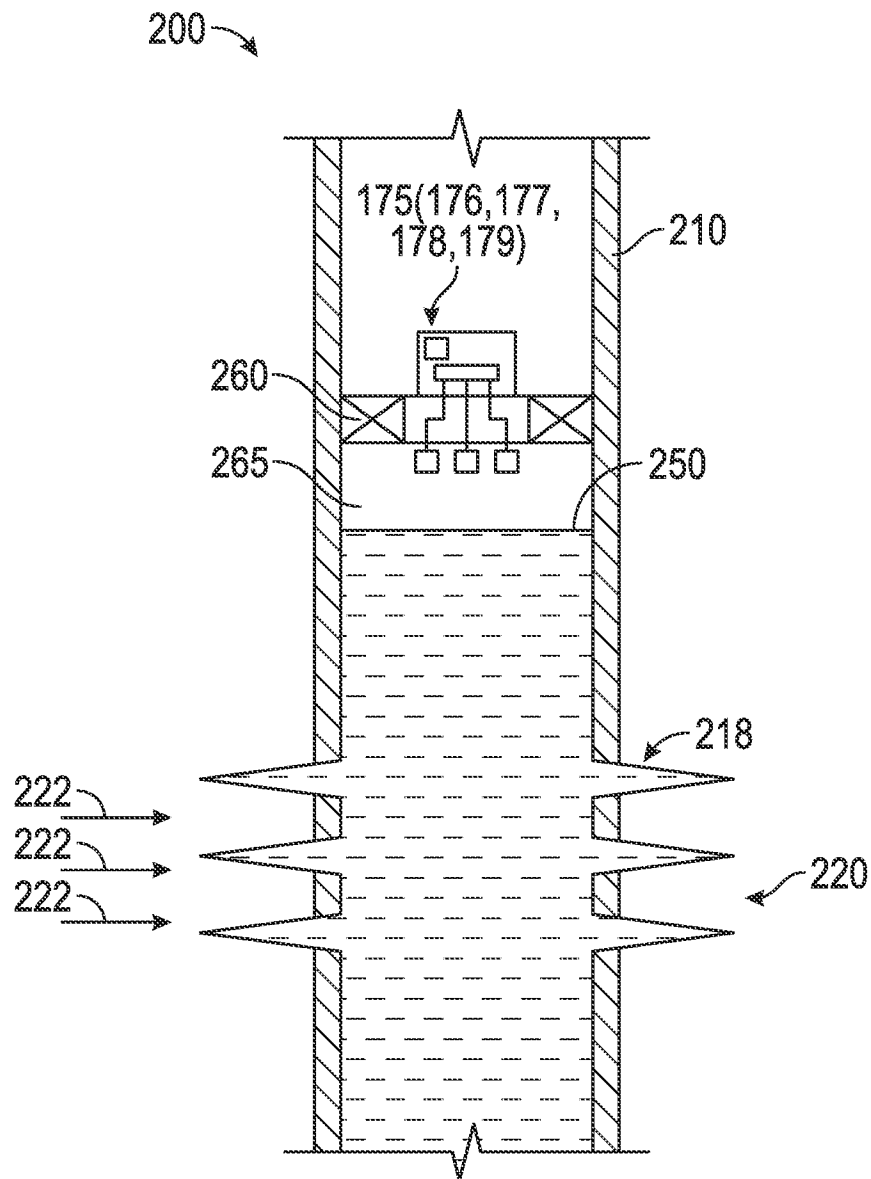


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/026761**A. CLASSIFICATION OF SUBJECT MATTER****E21B 47/10(2006.01)i, E21B 33/13(2006.01)i, E21B 47/12(2006.01)i**

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 47/10; E21B 33/00; E21B 47/00; E21B 47/16; E21B 33/14; E21B 33/13; G01V 1/40; E21B 49/08; E21B 47/12

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & keywords: cement, plug, sensor, processor, leak, transmitter, and receiver

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013-0299165 A1 (CROW, WALTER PATRICK) 14 November 2013 See abstract, paragraphs [0026]-[0038], [0062], and figures 2A, 4A-4B, 6C.	1-24
A	US 2002-0179301 A1 (SCHULTZ et al.) 05 December 2002 See abstract, paragraphs [0019]-[0021], and figures 1-2.	1-24
A	US 2014-0126332 A1 (HALLIBURTON ENERGY SERVICES, INC.) 08 May 2014 See abstract, paragraphs [0016]-[0027], and figure 1.	1-24
A	US 8584756 B1 (HALLIBURTON ENERGY SERVICES, INC.) 19 November 2013 See abstract, column 4, line 52 - column 5, line 32, and figure 3.	1-24
A	US 5036916 A (BENNETT, FRANK) 06 August 1991 See abstract, column 5, line 22 - column 6, line 37, and figures 1-3.	1-24



Further documents are listed in the continuation of Box C.



See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/026761

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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