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(54) Title: SYSTEM AND METHODOLOGY FOR DISTRIBUTED INFLOW MONITORING

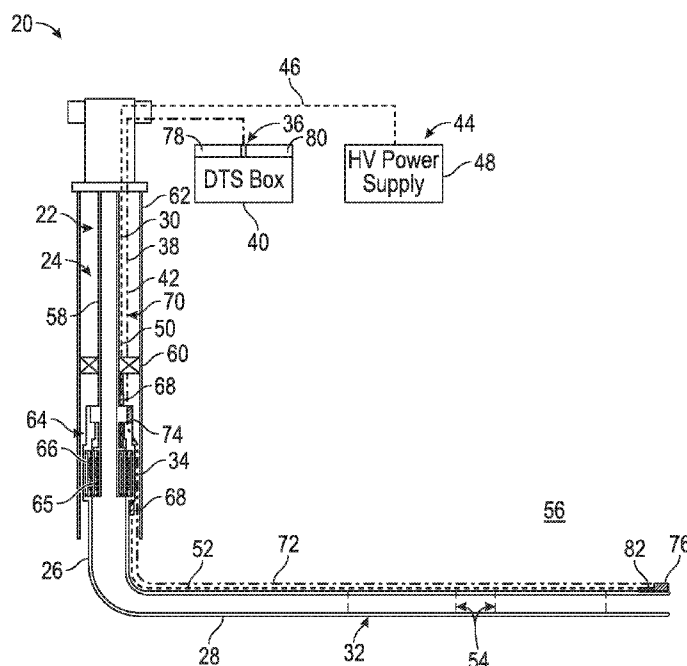


FIG. 1

(57) Abstract: A technique facilitates recovery of hydrocarbon fluids such as oil. A well system comprises a completion system having an upper completion, a lower completion, and an inductive coupler. Additionally, the overall well system may comprise a sensor system, e.g. a distributed sensor system having a fiber routed along the upper completion and the lower completion to monitor temperature and/or other parameters. The well system also may comprise a heating system having an upper portion coupled to the inductive coupler and a lower portion coupled to the inductive coupler. The lower portion may be deployed along the lower completion to provide heat. Based on data, e.g. temperature data, obtained from the sensor system, adjustments may be made to the heating system and/or other downhole components to facilitate hydrocarbon recovery.



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PATENT APPLICATION**SYSTEM AND METHODOLOGY FOR DISTRIBUTED INFLOW
MONITORING****CROSS-REFERENCE TO RELATED APPLICATION**

[0001] The present document is based on and claims priority to US Provisional Application Serial No.: 62/474425, filed March 21, 2017, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Hydrocarbon fluids, e.g. oil and natural gas, are recovered from subterranean formations. Recovery of the hydrocarbon fluids may involve drilling a well and deploying a completion system downhole in the well to facilitate the recovery process. The completion system may comprise sand screen assemblies, pumping systems, well treatment systems, and/or various other systems which are deployed downhole and work in cooperation to enable the recovery of the hydrocarbon fluids.

SUMMARY

[0003] In general, a system and methodology are provided for facilitating recovery of hydrocarbon fluids such as oil. According to an embodiment, a completion system is constructed for deployment downhole in a wellbore. The completion system may have an upper completion, a lower completion, and an inductive coupler. Additionally, the overall well system may comprise a sensor system, e.g. a distributed temperature sensor system having a fiber routed along the upper completion and the lower completion to monitor temperature along at least the lower completion. The well

system also may comprise a heating element system, e.g. a heating cable, having an upper portion coupled to the inductive coupler and a lower portion coupled to the inductive coupler. The lower portion of the heating element system may be deployed along the lower completion to provide heating along the lower completion. Based on data obtained from the distributed sensor system, adjustments may be made to the heating system and/or other downhole components to facilitate hydrocarbon recovery.

[0004] However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0006] Figure 1 is an illustration of an example of a well system utilizing a distributed sensor system and a heating system, according to an embodiment of the disclosure;

[0007] Figure 2 is an illustration of an example of a control line system having control line segments coupled together by a control line wet mate connector to facilitate deployment and use of the distributed sensor system, according to an embodiment of the disclosure; and

[0008] Figure 3 is an illustration of another example of a control line system having control line segments coupled together by a fiber wet mate connector to facilitate

deployment and use of the distributed sensor system, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0009] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0010] The disclosure herein generally involves a system and methodology useful for facilitating recovery of hydrocarbon fluids such as oil. According to an embodiment, an overall well system has a completion system constructed for deployment downhole in a wellbore. Depending on the application, the completion system may comprise many types of completion components.

[0011] In some embodiments, the completion system comprises sand screen assemblies having sand screens which may be used in combination with, for example, a gravel pack to filter particulates from inflowing well fluid, e.g. oil. The completion system also may comprise at least one pumping system, e.g. at least one electric submersible pumping system, operated to pump the inflowing well fluid to a surface collection location. However, the completion system may comprise a variety of additional or other components deployed in vertical wells or deviated wells, e.g. horizontal wells. According to an embodiment, the completion system may have an upper completion, a lower completion, and an inductive coupler. For some operations, the lower completion may comprise sand screen assemblies as discussed above.

[0012] Additionally, the overall well system may comprise a sensor system, e.g. a distributed temperature sensor system or other distributed sensor system having a fiber

routed along the completion system. For example, the fiber may be routed adjacent the upper completion and the lower completion. The sensor system may be operated to monitor a desired parameter or parameters, e.g. temperature, along portions of the completion system. For example, a distributed sensor system may be used to monitor the desired parameter or parameters along at least the lower completion.

[0013] The well system also may comprise a heating element system having an upper portion coupled to the inductive coupler and a lower portion coupled to the inductive coupler. The lower portion is constructed to enable the application of heat along, for example, the lower completion. According to an embodiment, the heating element system comprises a heating cable having an upper portion and a lower portion. In this embodiment, the lower portion of the heating cable may be deployed along the lower completion to provide heating along the lower completion. Based on data, e.g. temperature data, obtained from the distributed sensor system, e.g. distributed temperature sensor system, adjustments may be made to the heating system and/or other downhole components to facilitate hydrocarbon recovery. In other words, the distributed sensor system enables distributed inflow monitoring with respect to inflowing fluids to obtain data which may be used to determine appropriate adjustments to the system, e.g. applying increased electrical power for additional heating of inflowing oil.

[0014] Referring generally to Figure 1, an example of a well system 20 is illustrated as having a completion system 22 deployed in a wellbore 24. By way of example, the wellbore 24 may comprise a generally vertical wellbore section 26 and a deviated wellbore section 28, e.g. a horizontal wellbore section. In the embodiment illustrated, completion system 22 comprises an upper completion 30, a lower completion 32 coupled with the upper completion 30, and an inductive coupler 34.

[0015] The well system 20 further comprises a sensor system 36, e.g. a distributed temperature sensor system or other distributed sensor system having a fiber 38 coupled with a control system 40. By way of example, the control system 40 may be a surface control system, and the fiber 38 may be routed down along the completion system

22. The fiber 38 may be located within a tubular control line 42 or other suitable, protective structure. In some embodiments, other types of sensor systems may utilize a plurality of sensors deployed along the completion system 22, e.g. along the lower completion 32.

[0016] The well system 20 also may comprise a heating element system 44 to provide heat along, for example, lower completion 32. According to an embodiment, heating system 44 comprises a heating cable 46 coupled with a power supply 48, e.g. a high-voltage power supply which is able to provide high-voltage electrical power through the heating cable 46. The heating cable 46 may comprise an upper portion 50 coupled to the inductive coupler 34 and a lower portion 52 coupled to the inductive coupler 34.

[0017] In some embodiments, the upper portion 50 may comprise a large gauge monocable and the lower portion 52 may be constructed as a heating element to generate a desired heat output along, for example, the lower completion 32. It should be noted heating cable 46 may be constructed in a variety of configurations and its lower portion 52 may comprise many types of heating elements. The heating cable 46 may be integrated into other components of completion system 22 or it may be a separate component coupled with or otherwise positioned along completion system 22.

[0018] The heating cable lower portion 52 may be deployed along the lower completion 32 to operate in cooperation with the distributed temperature sensor system 36 (or other suitable sensor system). For example, the heating system 44 may be operated to provide heating based on temperature data obtained from the distributed temperature sensor system 36. In a specific example, the lower completion 32 comprises screen assemblies 54 which have screens through which well fluid flows into the lower completion 32 from a surrounding geologic formation 56. The lower portion 52 may be positioned along the screen assemblies 54 to provide heat as the well fluid flows into the screen assemblies. In some embodiments, the distributed sensor system 36 may be configured for monitoring additional or other types of parameters which can be used to determine a desired heat input to be applied via the lower portion/heating element 52

[0019] Based on data, e.g. temperature data, obtained via fiber 38, the power supply 48 may be operated to provide suitable electrical power through heating cable 46 so as to appropriately heat the inflowing well fluid. For example, the inflowing fluid may be heated to facilitate pumping of the well fluid to a desired collection location. However, various other or additional flow controls may be exercised based on the temperature data obtained. The distributed temperature sensor system 36 may be used to continually monitor temperature data during an operation in which heat is applied downhole via heating system 44. Continuous monitoring of the temperature of inflowing fluid also may facilitate decisions regarding other actions that may be taken to enhance the production operation.

[0020] With further reference to the embodiment illustrated in Figure 1, the upper completion 30 may comprise various features, such as a tubing 58 combined with a feed-through packer 60 which may be set against a surrounding casing 62 or other suitable surface. The upper completion 30 may be coupled with lower completion 32 via a suitable connector system 64. The components of upper completion 30 (as well as lower completion 32) may be selected according to the environment and objectives of a given operation.

[0021] In the embodiment illustrated, inductive coupler 34 is positioned proximate the connection between upper completion 30 and lower completion 32, e.g. proximate connector system 64. The inductive coupler 34 enables the wireless transfer of electrical power and/or other electrical signals between the upper and lower completions 30, 32. By way of example, the wireless transfer of electrical power may be achieved via an inductive coil or coils, e.g. the illustrated inductive coils 65 and 66, of inductive coupler 34. It should be noted the inductive coupler 34 is able to function as a transformer and the coils 65 and 66 may serve as primary and secondary sides of the transformer. Thus, the number of turns used in the respective coils 65, 66 may be different to provide, for example, a step down or step up transformer at inductive coupler

34. In other words, the inductive coupler 34 may be constructed to provide a desired transformer ratio between the primary and secondary sides.

[0022] In the example illustrated, the heating cable upper portion 50 may be connected with inductive coupler 34 via an electrical dry mate connector 68 or other suitable connector. Similarly, the heating cable lower portion 50 may be connected with inductive coupler 34 via a separate electrical dry mate connector 68 or other suitable connector.

[0023] The tubular control line 42 of the distributed temperature sensor system 36 may be assembled via connected control line portions. In the embodiment illustrated in Figure 2, for example, the tubular control line 42 comprises an upper control line portion 70 coupled with a lower control line portion 72 via control line connectors 74. In this example, connectors 74 may be part of a control line wet mate (CLWM) connector system, such as CLWM systems available from Schlumberger. In this embodiment, the fiber 38 may then be pumped through the connected control line 42. By way of example, the control line connectors 74 may be located in or proximate connector system 64 or at another suitable location.

[0024] In some embodiments, the tubular control line 42 may be constructed as a loop formed via adjacent control line tubes coupled with a fiber U-turn 76, as further illustrated in Figure 1. In this type of embodiment, the fiber 38, e.g. optical fiber, may be blown down through one control line tube of the tubular control line 42, through the fiber U-turn 76, and back up through the adjacent control line tube of tubular control line 42.

[0025] Referring generally to Figure 3, another embodiment of tubular control line 42 is illustrated. The tubular control line 42 again comprises upper control line portion 70 coupled with lower control line portion 72. In this embodiment, however, the control line portions 70, 72 are constructed with internal fiber and coupled via a different type of control line connectors 77. The control line portions 70, 72 each contain a

corresponding portion of the fiber 38 which terminates at the corresponding connector 77.

[0026] Thus, the connectors 77 are constructed to provide a fiber wet mate connector able to couple both the segments of fiber 38 and the surrounding tubing of control line portions 70, 72. In this embodiment, the sections of fiber 38 are prepackaged in corresponding control line portions 70, 72 and then connected via the fiber wet mate connector system when joining control line portions 70 and 72. The control line connectors 77 may be located in or proximate connector system 64 or at another suitable location.

[0027] As illustrated in Figure 1, the distributed temperature sensor control system 40 also may comprise a light signal source 78 for directing light signals through the optical fiber 38 and a light signal receiver 80 for receiving the returning light signals. The returning light signals are then processed via control system 40 to evaluate a given parameter or parameters, e.g. temperature. For example, the control system 40 may be used to process data indicating temperature and temperature changes along the optical fiber 38. Based on the data collected via distributed sensor system 36, the power supply 48 may be operated to provide the desired electrical power and thus the desired heat at locations downhole, e.g. along lower completion 32.

[0028] In some applications, the control system 40 and heating system 44 may be operatively coupled to enable automated adjustments. For example, the control system 40 may process data obtained from sensor system 36 and, based on that processed data, perform automatic adjustments with respect to the downhole heating and/or with respect to operation of other downhole devices. Automatic adjustments to the electrical power delivered to lower portion 52 (and thus to the heat applied via lower portion 52) may be based on, for example, the temperatures monitored via distributed temperature sensor system 36.

[0029] According to an embodiment, the heating cable 46 may be terminated to the completion system 22 via a heating cable termination 82. For example, the heating cable 46 may be grounded to lower completion 32 or to another suitable portion of completion system 22 via termination 82. In some embodiments, the termination may be achieved by forming the heating cable 46 with multiple cables routed through U-turns.

[0030] Depending on the parameters of a given operation, many types of completion systems 22 may be utilized. Additionally, various types of inductive couplers 34 may be constructed to enable the wireless transfer of electrical power between sections of the completion system 22, e.g. between the upper completion 30 and the lower completion 32. In some embodiments, the inductive coupler 34 may have different numbers of turns at the primary and secondary to allow, for example, stepping down of the voltage while having more current circulating in the heating cable 46. The power supply 48 also may be constructed to supply suitable voltages for a given heating operation, e.g. voltages above 1000 V, above 2000 V, above 3000 V, or at other suitable voltages.

[0031] The heating cable 46 may be selected according to the environment in which it is utilized and according to the power/voltage supplied downhole via power supply 44. In some applications, the impedance of the heating cable 46 may determine the choice of voltage suitable for the inductive coupler 34, e.g. suitable for an inductive coupler secondary. Additionally, the sensor system 36, e.g. distributed temperature sensor system, and the heating system 44 may be used in cooperation to achieve various types of control over well operations, e.g. control over flow in production operations. Various types of optical fibers, tubular control lines, connectors, terminations, and/or other components may be selected according to the parameters of a given operation.

[0032] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this

disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

What is claimed is:

1. A system for use in a well, comprising:
 - a completion system having an upper completion, a lower completion, and an inductive coupler;
 - a distributed temperature sensor system having a fiber routed along the upper completion and the lower completion to monitor temperature along at least the lower completion; and
 - a heating cable having an upper portion coupled to the inductive coupler and a lower portion coupled to the inductive coupler, the lower portion being deployed along the lower completion to provide heating which is monitorable to obtain temperature data via the distributed temperature sensor system.
2. The system as recited in claim 1, wherein the lower completion comprises a plurality of sand screens.
3. The system as recited in claim 1, wherein the fiber is disposed within a tubular control line.
4. The system as recited in claim 3, wherein the tubular control line has an upper control line portion coupled with a lower control line portion.
5. The system as recited in claim 3, wherein the tubular control line comprises a loop formed by adjacent control line tubes coupled via a fiber U-turn.
6. The system as recited in claim 1, wherein the distributed temperature sensor system comprises a surface control coupled with the fiber, the surface control having a light signal source and a light signal receiver.

7. The system as recited in claim 1, further comprising a high voltage power supply coupled with the heating cable.
8. The system as recited in claim 7, wherein the inductive coupler transmits electrical power wirelessly to the lower portion of the heating cable.
9. The system as recited in claim 8, wherein the heating cable is grounded to the lower completion.
10. The system as recited in claim 1, wherein the inductive coupler presents a transformer ratio.
11. A method, comprising:
 - deploying a lower completion into a borehole;
 - positioning a distributed sensor along the lower completion; and
 - locating an inductive coupler downhole in the borehole with a heating cable having an upper portion coupled to the inductive coupler and a lower portion coupled to the inductive coupler and deployed along the lower completion.
12. The method as recited in claim 11, further comprising heating the lower portion by supplying electrical power to the inductive coupler and wirelessly communicating the electrical power to the lower portion.
13. The method as recited in claim 11, further comprising coupling an upper completion to the lower completion at the inductive coupler.
14. The method as recited in claim 12, further comprising using the distributed sensor to monitor heat produced by the lower portion, and adjusting the electrical power provided to the lower portion in response to data obtained via the monitoring.

15. The method as recited in claim 12, further comprising using the distributed sensor to monitor heat produced by the lower portion, and adjusting a feature of the lower completion in response to data obtained via the monitoring.
16. The method as recited in claim 11, wherein positioning comprises positioning an optical fiber along the lower completion to enable distributed temperature sensing.
17. The method as recited in claim 16, wherein positioning comprises deploying the optical fiber in a protective tube.
18. A method, comprising:
 - providing electrical power to a downhole heating element across an inductive coupler to enable wireless transfer of electrical power to the heating element;
 - using the heating element to heat a borehole region along a downhole completion; and
 - monitoring changes in parameters of the borehole region resulting from heat applied via the heating element.
19. The method as recited in claim 18, wherein using the heating element comprises heating a hydrocarbon fluid in the borehole region to facilitate production of the hydrocarbon fluid.
20. The method as recited in claim 18, wherein monitoring comprises monitoring with a distributed temperature sensor having an optical fiber; and further comprising adjusting the electrical power supplied based on data obtained from the distributed temperature sensor.

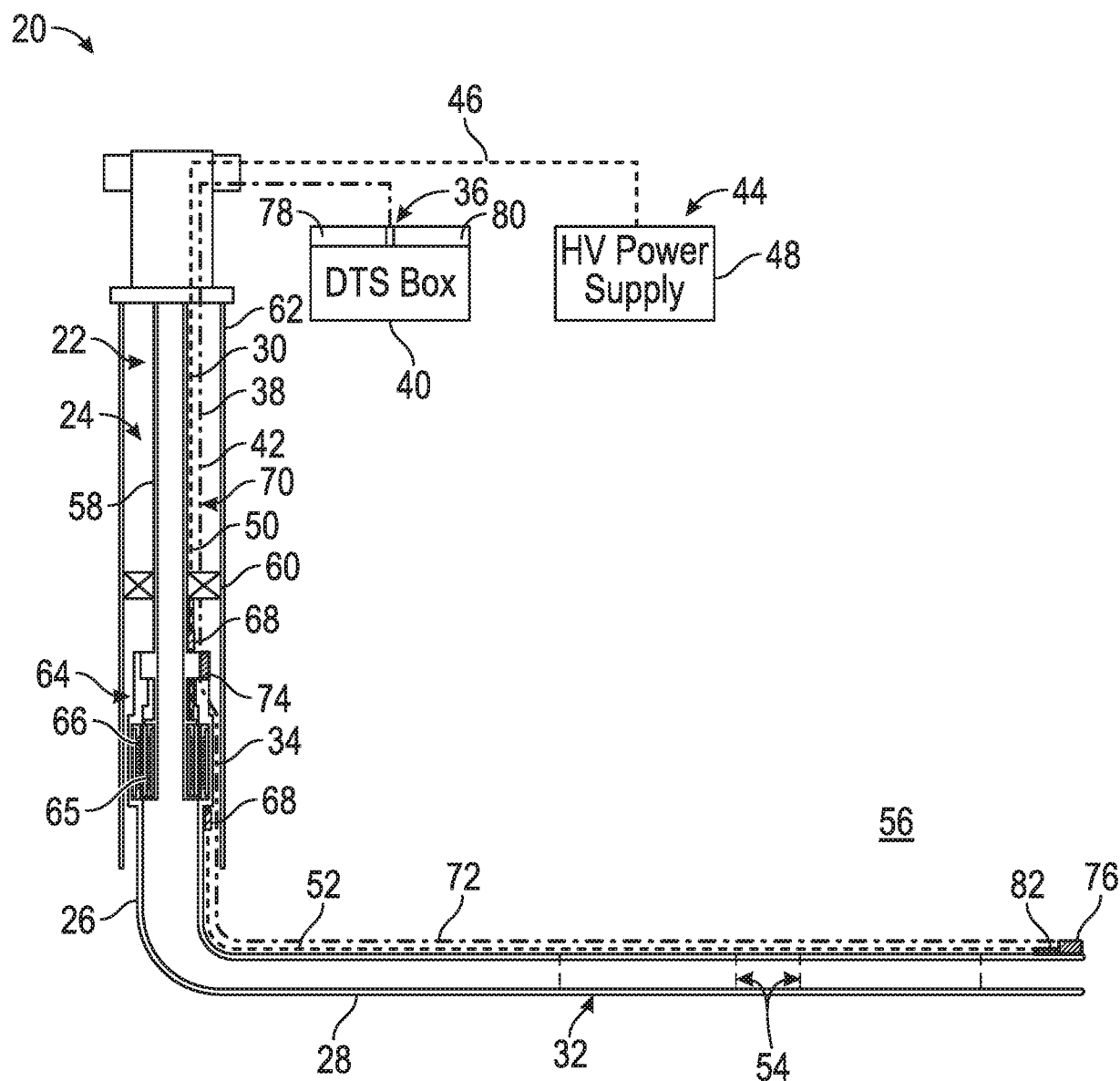


FIG. 1

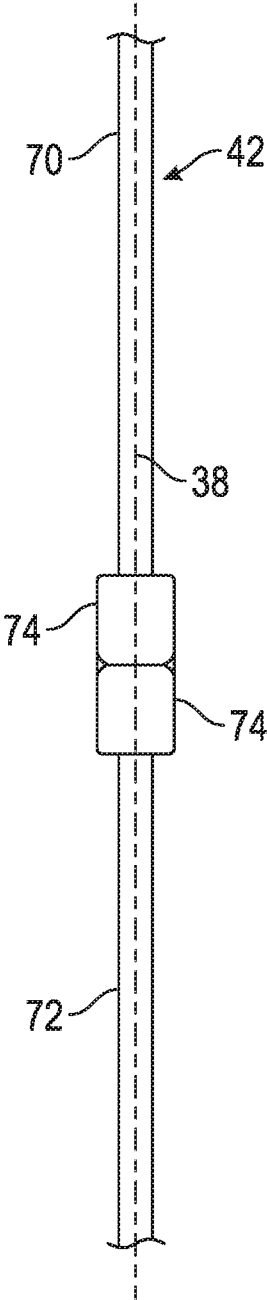


FIG. 2

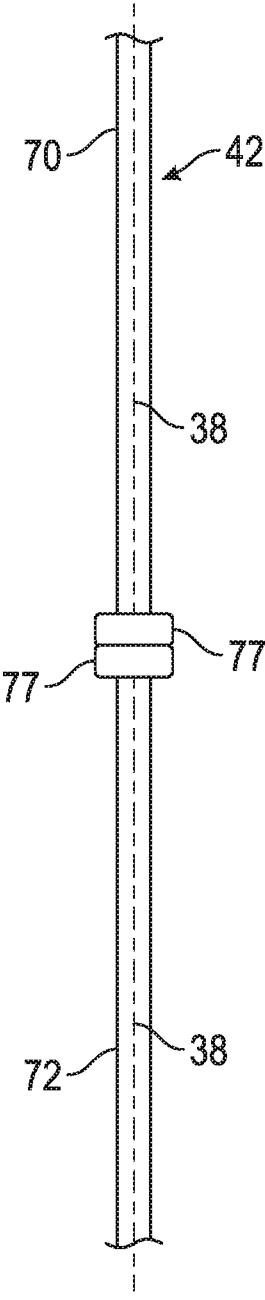


FIG. 3

A. CLASSIFICATION OF SUBJECT MATTER**E21B 36/04(2006.01)i, E21B 47/06(2006.01)i, E21B 43/08(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 36/04; E21B 47/00; E21B 34/06; F24H 1/10; E21B 23/00; E21B 36/02; E21B 47/06; E21B 43/08

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: completion system, temperature sensor, heating cable, control line, inductive coupler**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010-0101786 A1 (LOVELL et al.) 29 April 2010 See paragraphs [0021]-[0031] and figure 3.	1-20
Y	US 6564011 B1 (JANOFF et al.) 13 May 2003 See column 2, line 49 - column 3, line 13, column 4, lines 22-44, claim 1, and figure 1.	1-20
A	US 2012-0138310 A1 (LAKE, GARY B.) 07 June 2012 See paragraphs [0009]-[0014] and figures 1-3.	1-20
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A	US 2015-0013962 A1 (INVIERNO, PABLO JAVIER) 15 January 2015 See paragraphs [0016]-[0018] and figures 1-3.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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