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(54) Title: METHODS AND SYSTEMS EMPLOYING AN ELECTRICALLY POWERED CROSSOVER SERVICE TOOL

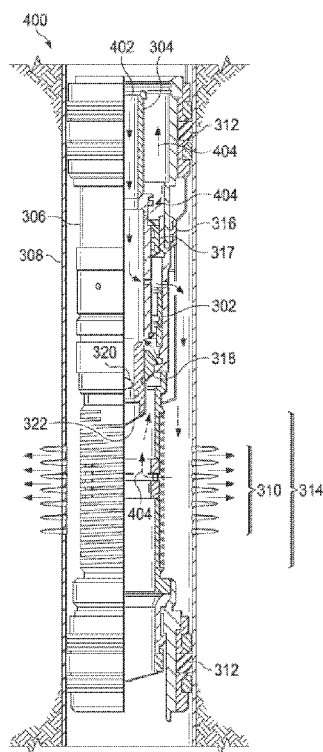


FIG. 4

(57) Abstract: A crossover service tool includes a tool body and crossover components integrated with the tool body to control a direction of fluid circulation into and out of the tool body. The crossover service tool also includes an electrically-powered actuator and a latch coupled to the electrically-powered actuator. The crossover service tool also includes a power/communications coupler to convert electrical signals to another type of signals and vice versa. A related system includes a crossover service tool in a downhole environment, the crossover service tool having an electrically-powered actuator and a latch coupled to the electrically-powered actuator. The system also includes a sand control assembly and an electrical power source to provide electrical power to the electrically-powered actuator. The electrically-powered actuator operates to move the latch relative to the sand control assembly.



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METHODS AND SYSTEMS EMPLOYING AN ELECTRICALLY-POWERED CROSSOVER SERVICE TOOL

BACKGROUND

5 In the oil and gas industry, sand control assemblies are sometimes deployed downhole to allow production of hydrocarbons while reducing the amount of sand produced. Sand control assemblies may vary with regard to screens, packers, and valves. To deploy a sand control assembly downhole and to perform related packing operations, a crossover service tool is often used to control circulation of fluids. As an example, a
10 crossover service tool and sand control assembly may be lowered into a borehole using available work string components. As traditional work string components do not support conveying power from earth's surface to the end of the work string, common operations of a crossover service tool (e.g., latching, unlatching, controlling circulation of fluids) do not involve electrical power. Instead, mechanical movement and/or fluid pressure adjustments
15 are used to perform crossover service tool operations.

Another type of assembly that is sometimes deployed downhole is referred to as an intelligent completion assembly. An intelligent completion assembly provides remote flow control options and data collection options that are traditionally not available with a sand control assembly. The service tools used to deploy or adjust an intelligent completion
20 assembly are not the same as the crossover service tool used for sand control assemblies as crossover service tools are not compatible with intelligent completion assemblies. The different service tools and number of service trips used to deploy and/or adjust sand control assemblies and intelligent completion assemblies represents a significant cost.

25 BRIEF DESCRIPTION OF THE DRAWINGS

Accordingly, there are disclosed in the drawings and the following description methods and systems employing an electrically-powered crossover service tool. In the drawings:

FIG. 1 is a schematic diagram showing an illustrative downhole environment.

30 FIGS. 2A and 2B are schematic diagrams showing features of an illustrative crossover service tool.

FIG. 3 is a cut-away view showing an illustrative crossover service tool and a sand control assembly.

FIG. 4 is a cut-away view showing fluid flow during a gravel packing process.

FIG. 5 is a cut-away view showing an illustrative crossover service tool and a sand control assembly in an open borehole environment.

FIG. 6 is a flow chart of a method employing an electrically-powered crossover service tool.

It should be understood, however, that the specific embodiments given in the drawings and detailed description thereto do not limit the disclosure. On the contrary, they provide the foundation for one of ordinary skill to discern the alternative forms, equivalents, and modifications that are encompassed together with one or more of the given embodiments in the scope of the appended claims.

DETAILED DESCRIPTION

Disclosed herein are methods and systems employing an electrically-powered crossover service tool. In at least some embodiments, a crossover service tool includes a tool body and crossover components integrated with the tool body to control a direction of fluid circulation into and out of the tool body. The crossover service tool also includes an electrically-powered actuator and a latch coupled to the electrically-powered actuator. The electrically-powered actuator may correspond to an electro-hydraulic actuator or an electro-mechanical actuator (e.g., a motor and linear displacement arrangement). The latch can be moved radially or axially by the actuator to facilitate the crossover service tool latching to or unlatching from a sand control assembly. The crossover service tool also includes a power/communications (P/C) coupler to change electrical signals to another type of signal (e.g., acoustic) or vice versa. The P/C coupler enables wired or wireless conveyance of power or communications between the crossover service tool and sand control assembly. Example P/C couplers may include inductive antennas, acoustic transducers, an electrical plug and related actuator (to move the plug to contact a corresponding slot in the sand control assembly). In such case, a sand control assembly may likewise include a corresponding P/C coupler to convert electrical signals to another type of signal (e.g., acoustic) or vice versa. With the P/C couplers, power or signals provided to the crossover service tool can be conveyed to components (e.g., actuators or sensors) of a sand control assembly. Furthermore, the P/C couplers enable data collected by one or more sensors deployed along a sand control assembly to be conveyed to earth's surface (or at least to a data storage unit included with the crossover service tool).

It should be appreciated that electrically-powered crossover service tools as

described herein may be used with unpowered sand control assemblies and/or with sand control assemblies that are customized to receive power or communications from the electrically-powered crossover service tool. In different embodiments, the electrically-powered crossover service tool receives electrical power from a wired connection (e.g.,
5 wired pipe, control line, and connectors) to a power supply at earth's surface and/or from a downhole power supply (e.g., a battery or downhole power generator).

In at least some embodiments, an example method includes deploying a crossover service tool in a downhole environment, where the crossover service tool has an electrically-powered actuator. The method also comprises moving a component of the
10 crossover service tool relative to a sand control assembly by providing electrical power to the actuator. As an example, the actuator may correspond to an electro-hydraulic or electro-mechanical actuator that moves a latch of the crossover service tool relative to the sand control assembly.

In at least some embodiments, an example system includes a crossover service tool
15 having an electrically-powered actuator and a latch coupled to the electrically-powered actuator. The system also includes a sand control assembly. The system also includes an electrical power source to provide electrical power to the electrically-powered actuator, where the electrically-powered actuator operates to move the latch relative to the sand control assembly.

20 The disclosed crossover service tool and related methods and systems are best understood when described in an illustrative usage context. FIG. 1 shows an illustrative downhole environment 100. In FIG. 1, a borehole 16 is represented as having been drilled and a casing 52 installed. To drill the borehole 16, a drilling platform 2 supports a derrick 4 having a traveling block 6 for raising and lowering a tubular string assembly 8. A tubular
25 string assembly kelly 10 supports the rest of the tubular string assembly 8 as it is lowered through a rotary table 12. The rotary table 12 rotates the tubular string assembly 8, thereby turning a drill bit (not shown). Additionally or alternatively, rotation of the drill bit is controlled using a mud motor or other rotation mechanism (not shown). As the drill bit rotates, it creates the borehole 16 (represented using dashed lines) that passes through various
30 formations. During drilling operations, a pump 20 circulates drilling fluid through a feed pipe 22 to the kelly 10, downhole through the interior of tubular string assembly 8, through orifices in the drill bit, back to the surface via an annulus 9 around the tubular string assembly 8, and into a retention pit 24. The drilling fluid transports cuttings from the borehole 16 into the

retention pit 24 and aids in maintaining the integrity of the borehole 16.

To install the casing 52, modular casing segments are joined and lowered into the borehole 16 until a desired casing section length is reached. Once a desired length and position for a particular casing section is achieved, cementing operations are performed, resulting in a permanent casing section installation. As needed, the borehole 16 is extended by drilling through cured cement at an installed casing section terminus. The process of installing casing sections, cementing the installed casing sections in place, and extending borehole 16 can be repeated as desired.

In FIG. 1, a crossover service tool 104 and a sand control assembly 102 are also represented, where the function of the crossover service tool 104 is to convey the sand control assembly 102 to its position along casing 52 and/or to support sand packing or gravel packing operations. An illustrative packing operation is later described (see FIG. 4). The crossover service tool 104 also supports latching/unlatching operations involving an electrically-powered actuator 106. Further, the crossover service tool 104 supports conveyance of power and/or communications to the sand control assembly 102 using an P/C coupler 108 that converts electrical signals to another type of signals (the sand control assembly 102 would include a corresponding P/C coupler). The P/C coupler 108 also enables the crossover service tool 104 to receive data collected by sensors deployed along the sand control assembly 102.

In different embodiments, the power used by the crossover service tool 104 and/or the sand control assembly 102 is provided by a wired connection between a power supply at earth's surface and the crossover service tool 104. For example, the wired connection may be provided, at least in part, by tubular string assembly 8 (a wired pipe arrangement). Alternatively, electrical conduits (not shown) may be mechanically attached to the outer diameter of the tubular string assembly 8. In such case, power and communications can be conveyed between earth's surface and the crossover service tool 104. In at least some embodiments, power and/or communications received by the crossover service tool 104 can be conveyed to sand control assembly 102 using P/C couplers 108 that convert electrical signals to another type of signals and vice versa. Likewise, data and/or acknowledgement signals originating from components of the sand control assembly 102 can be transferred to the crossover service tool 104. The data and/or acknowledgement signals received by the crossover service tool 104 from the sand control assembly 102 can be conveyed to earth's surface via the wired connection. Additionally or alternatively, the

data and/or acknowledgement signals are stored in a local data storage unit included with the crossover service tool 104. In some embodiments, at least some of the power used by the crossover service tool 104 and/or the sand control assembly 102 is provided by a downhole power supply (e.g., a battery or downhole power generator) included with the crossover service tool 104.

FIGS. 2A and 2B are schematic diagrams showing features of an illustrative crossover service tool 200. Without limitation to other embodiments, the crossover service tool 200 of FIGS. 2A and 2B includes a tool body 204 with various crossover components including a tool center section 202, an inner central conduit 206, a plurality of axial conduits 208, and at least one radial conduit 210. The crossover components control of fluid circulation during packing operations or other operations. The crossover service tool 200 also includes a collet or latch 212. In at least some embodiments, the collet or latch 212 includes at least one latching profile 214 to facilitate latching operations. As desired, the collet or latch 212 expands and retracts radially as directed by an electrically-powered actuator 215. Additionally or alternatively, the collet or latch 212 may be directed to move axially (up or down) by the same electrically-powered actuator 215 or by another electrically-powered actuator (not shown) such as an electrically-powered ball valve. By controlling the position and/or diameter of the collet or latch 212, the crossover service tool 200 can latch to or unlatch from different sand control assemblies deployed along a casing or borehole, even if the diameters associated with the different sand control assemblies are different. When latched to a sand control assembly, the tool body 204, the inner central conduit 206, the axial conduits 208, and the at least one radial conduit 210 enable the crossover service tool 200 to control fluid circulation as needed for packing operations. During packing operations, changing the direction of fluid circulation is sometimes needed. In such case, the position of a ball valve 216 is adjusted. In some embodiments, adjusting the position of the ball valve 216 is performed using known techniques such as by changing the fluid pressure inside the crossover service tool 200 or by the use of an actuator, said actuator (not shown) may be powered mechanically, electrically, or hydraulically.

The crossover service tool 200 is also shown to include a P/C coupler 218. It should be appreciated that the position of the P/C coupler 218 may vary for different embodiments. Regardless of position, the P/C coupler 218 allows for electrical signals to be converted to other types of signals (e.g., acoustic signals). As desired, sand control assemblies can be customized to include corresponding P/C couplers (within range and compatible with P/C

coupler 218) to enable power and/or data to be transferred between the crossover service tool 200 and a sand control assembly. While not required, the functionality of sand control assemblies can be enhanced using power and communications available using P/C couplers as described herein.

5 FIG. 3 shows a downhole environment 300, where a crossover service tool 302 and a sand control assembly 306 are represented using a cut-away view. . In FIG. 3, the illustrated crossover service tool 302 is inside and latched to the sand control assembly 306, and the sand control assembly 306 has been set at a target position along a casing string 308. For example, the target position for the sand control assembly 306 may align a screen 10 314 of the sand control assembly 306 with fractures 310 that extend through the casing string 308 and into the surrounding formation. Once in its target position, isolation packers 312 of the sand control assembly 306 can be activated by applying hydraulic pressure or by utilizing a device housing an actuator that, when commanded, can set the packer to seal the annular space between the sand control assembly 306 and the casing string 308 at points 15 above and below the screen 314. Once isolated in this manner, the sand control assembly 306 can be used in a production scenario, where fluid enters the casing string 308 through the fractures 310 and is forced to pass through the screen 314. Before such production begins, sand or gravel packing can be performed to fill the exterior space around the screen 314 with sand or gravel having a grain size that is unable to pass through the screen 314. 20 The packed sand or gravel deposited during packing operations serves to reduce the amount of finer grain material that would otherwise pass through the screen 314. When latched to the sand control assembly 306, the crossover service tool 302 enables the fluid circulation needed to perform sand or gravel packing operations.

Without limitation to other embodiments, some of the other components 25 represented in FIG. 3 include a wired connection 304 that provides power from a power supply at earth's surface to the crossover service tool 302. The wired connection 304 may be achieved, for example, using wired pipe and suitable connectors. Also represented in FIG. 3, is a latch 318 of the crossover service tool 302. In at least some embodiments, the latch 318 moves radially or axially as directed by one or more electrically-powered 30 actuators to facilitate latching and unlatching of the crossover service tool 302. Also represented is a ball valve 320 of the crossover service tool 302, where the ball valve 320 enables the direction of fluid circulation to be reversed. Further, a P/C coupler 317 of the crossover service tool 302 is represented, where the P/C coupler 317 can convert electrical

signals to another type of signals (e.g., acoustic signals) and vice versa. A corresponding P/C coupler 316 deployed along the sand control assembly 306 is also represented. The P/C coupler 316 of the sand control assembly 306 should be within range and should be compatible with the P/C coupler 317 of the crossover service tool 302. With power and communications available via the P/C couplers 317 and 316, the represented sand control assembly 306 also includes at least one sensor 330 and at least one actuator 322. While the sensor 330 and the actuator 322 are represented as being positioned along the screen 314, it should be appreciated that sensors and/or actuators can be positioned elsewhere along the sand control assembly 306.

FIG. 4 shows a cased downhole environment 400 similar to downhole environment 300 of FIG. 3, but where fluid flow during a sand packing operation is represented using arrows. In the cased downhole environment 400, a slurry (represented using solid arrows 402) including gravel or sand passes through a conduit of the crossover service tool 302 and eventually out into the space external to the screen 314 of the sand control assembly 306. The gravel or sand becomes packed in the region external to the screen 314, while the fluid portion of the slurry (represented using dashed arrows 404) passes through the screen 314 and is circulated back toward earth's surface through the crossover service tool 302. As needed, the direction of fluid flow through the crossover service tool 302 may be reversed. For example, when the space external to the screen 314 is fully packed, the remaining slurry can be removed by reversing the direction of circulation. In such case, the ball valve 320 is open and the direction of fluid is reversed without disturbing the packed sand or gravel.

FIG. 5 shows an openhole downhole environment 500, where a crossover service tool 506 and a sand control assembly 504 are represented using a cut-away view. The environment includes open borehole annulus 502. In openhole downhole environment 500, the features and operations of the sand control assembly 504 and the crossover service tool 506 may correspond respectively to the features and operations described for sand control assembly 306 and the crossover service tool 302 described previously for FIG. 4, except no casing string is present. In such case, fluid circulation is still needed to perform sand or gravel packing operations, and the fluid circulation is controlled using the crossover service tool 506. Further, the crossover service tool 506 may include at least one electrically-powered actuator and at least one P/C coupler as described herein. Further, the sand control assembly 504 may include a corresponding P/C coupler, electrically-powered actuators,

and sensors as described herein. Further, washdown capability components can be included with the sand control assembly 504.

FIG. 6 is a flow chart showing an example method 600 employing an electrically-powered crossover service tool. At block 602, a sand control assembly is coupled to the crossover service tool and is deployed downhole using a tubular string assembly. For example, the tubular string assembly may correspond to the same tubular components as those used for drilling operations. At block 604, the sand control assembly and crossover service tool is moved to a target position. The target position may correspond to a predetermined position along a cased borehole or open borehole, where a sand control assembly is to be positioned or is already positioned as described herein. Assuming the crossover service tool and sand control assembly were not deployed together (as may be the case in some scenarios), the crossover service tool latches to the sand control assembly using an electrically-powered actuator at block 606. As described herein, latching a crossover service tool to a sand control assembly may involve moving a latch radially or axially using at least one electrically-powered actuator. At block 608, electrical signals are converted, by the crossover service tool, to another type of signals for use by the sand control assembly. As an example, both the crossover service tool and the sand control assembly may include acoustic transducers to convert electrical signals to acoustic signals and vice versa as described herein. With power and communications made available at block 608, the sand control assembly performs operations such as collecting temperature measurements, pressure measurements, and/or other measurements during a sand packing operation. The collected measurements can be used to identify when a packing operation is complete, or when an issue arises. Further, an electrically-powered actuator deployed along the sand control assembly can adjust a valve or sliding sleeve using the power and communications made available at block 608. As an example, an electrically-powered actuator deployed along the sand control assembly may adjust the amount of fluid that flows through a screen of the sand control assembly, or may control fluid loss after a gravel pack operation by closing a sliding sleeve. Other adjustments are possible as well. At block 610, the crossover service tool unlatches from the sand control assembly using an electrically-powered actuator and moves to another target position. For example, the next target position may correspond to another sand control assembly. Accordingly, it should be appreciated that with an electrically-powered crossover service tool as described herein may latch to and unlatch from different sand control assemblies having different diameters

without removing the crossover service tool from the downhole environment.

Embodiments disclosed herein include:

A: A method that comprises deploying a crossover service tool in a downhole environment, the crossover service tool having an electrically-powered actuator. The method also comprises moving a component of the crossover service tool relative to a sand control assembly by providing electrical power to said actuator.

B: A system that comprises a crossover service tool in a downhole environment, the crossover service tool having an electrically-powered actuator and a latch coupled to the electrically-powered actuator. The system also comprises a sand control assembly and an electrical power source for providing electrical power to the electrically-powered actuator. The electrically-powered actuator operates to move the latch relative to the sand control assembly.

C: A crossover service tool that comprises a tool body and crossover components integrated with the tool body to control a direction of fluid circulation into and out of the tool body. The crossover service tool also comprises an electrically-powered actuator a latch coupled to the electrically-powered actuator. The crossover service tool also comprises a power/communications coupler to convert electrical signals to another type of signals and vice versa.

Each of embodiments A, B, and C may have one or more of the following additional elements in any combination: Element 1: wherein said moving a component comprises moving a latch in a radial direction. Element 2: wherein said moving a component comprises moving a latch in an axial direction. Element 3: further comprising providing power or communications via the crossover service tool to one or more sensors deployed along a sand control assembly. Element 4: further comprising collecting data from the one or more sensors during a sand-packing operation. Element 5: further comprising providing power via the crossover service tool to one or more electrically-powered actuators deployed along a sand control assembly. Element 6: further comprising transducing, by the crossover service tool, electrical signals to another type of signals, and restoring the other type of signals to electrical signals for use by a sand control assembly. Element 7: wherein said providing electrical power involves a downhole battery or downhole power generator. Element 8: wherein said providing electrical power involves a wired pipe. Element 9: wherein the electrically-powered actuator is an electro-mechanical actuator. Element 10: wherein the electrically-powered actuator is an electro-hydraulic actuator. Element 11:

wherein the crossover service tool and the sand control assembly comprise power/communications couplers to transfer electrical power or communications to at least one component deployed along the sand control assembly. Element 12: wherein the at least one component deployed along the sand control assembly includes a sensor. Element 13: 5 wherein the at least one component deployed along the sand control assembly includes an electrically-powered actuator. Element 14: wherein the electrical power source includes a power supply at earth's surface and a wired pipe coupled to the crossover service tool. Element 15: wherein the electrical power source includes a downhole battery. Element 16: wherein the power/communications coupler converts electrical signals to acoustic signals 10 and vice versa to transfer power or communications between the crossover service tool and a sand control assembly. Element 17: wherein the electrically-powered actuator is an electro-hydraulic actuator. Element 18: wherein the electrically-powered actuator is an electro-mechanical actuator.

Numerous other modifications, equivalents, and alternatives, will become apparent 15 to those skilled in the art once the above disclosure is fully appreciated. It is intended that the following claims be interpreted to embrace all such modifications, equivalents, and alternatives where applicable.

CLAIMS

WHAT IS CLAIMED IS:

1. A method, comprising:
 - deploying a crossover service tool in a downhole environment, the crossover service
 - 5 tool having an electrically-powered actuator; and
 - moving a component of the crossover service tool relative to a sand control assembly by providing electrical power to said actuator.
2. The method of claim 1, wherein said moving a component comprises moving a latch in a radial direction.
- 10 3. The method of claim 1, wherein said moving a component comprises moving a latch in an axial direction.
4. The method of claim 1, further comprising providing power or communications via the crossover service tool to one or more sensors deployed along the sand control assembly.
5. The method of claim 4, further comprising collecting data from the one or more
- 15 sensors during a sand-packing operation.
6. The method of claim 1, further comprising providing power via the crossover service tool to one or more electrically-powered actuators deployed along the sand control assembly.
7. The method of claim 1, further comprising transducing, by the crossover service
- 20 tool, electrical signals to another type of signals, and restoring the other type of signals to electrical signals for use by a sand control assembly.
8. The method according to any one of claims 1 to 7, wherein said providing electrical power involves a downhole battery or downhole power generator.
9. The method according to any one of claims 1 to 7, wherein said providing electrical
- 25 power involves a wired pipe.
10. A system, comprising:
 - a crossover service tool in a downhole environment, the crossover service tool having an electrically-powered actuator and a latch coupled to the electrically-powered
 - 30 actuator;
 - a sand control assembly; and
 - an electrical power source to provide electrical power to the electrically-powered actuator,

wherein the electrically-powered actuator operates to move the latch relative to the sand control assembly.

11. The system of claim 12, wherein the electrically-powered actuator is an electro-mechanical actuator.

5 12. The system of claim 12, wherein the electrically-powered actuator is an electro-hydraulic actuator.

13. The system of claim 12, wherein the crossover service tool and the sand control assembly comprise power/conditioning couplers to transfer electrical power or communications to at least one component deployed along the sand control assembly.

10 14. The system of claim 16, wherein the at least one component deployed along the sand control assembly includes a sensor.

15. The system of claim 16, wherein the at least one component deployed along the sand control assembly includes an electrically-powered actuator.

16. The system according to any one of claims 12 to 18, wherein the electrical power source includes a power supply at earth's surface and a wired pipe coupled to the crossover service tool.

17. The system according to any one of claims 12 to 18, wherein the electrical power source includes a downhole battery.

20 18. A crossover service tool, comprising:

 a tool body;

 crossover components integrated with the tool body to control a direction of fluid circulation into and out of the tool body;

 an electrically-powered actuator;

25 a latch coupled to the electrically-powered actuator; and

 a power/communications coupler to convert electrical signals to another type of signals and vice versa.

19. The crossover service tool of claim 18, wherein the power/communications coupler converts electrical signals to acoustic signals and vice versa to transfer power or communications between the crossover service tool and a sand control assembly.

20. The crossover service tool of claim 18, wherein the electrically-powered actuator is an electro-hydraulic actuator.

21. The crossover service tool of claim 18, wherein the electrically-powered actuator is an electro-mechanical actuator.

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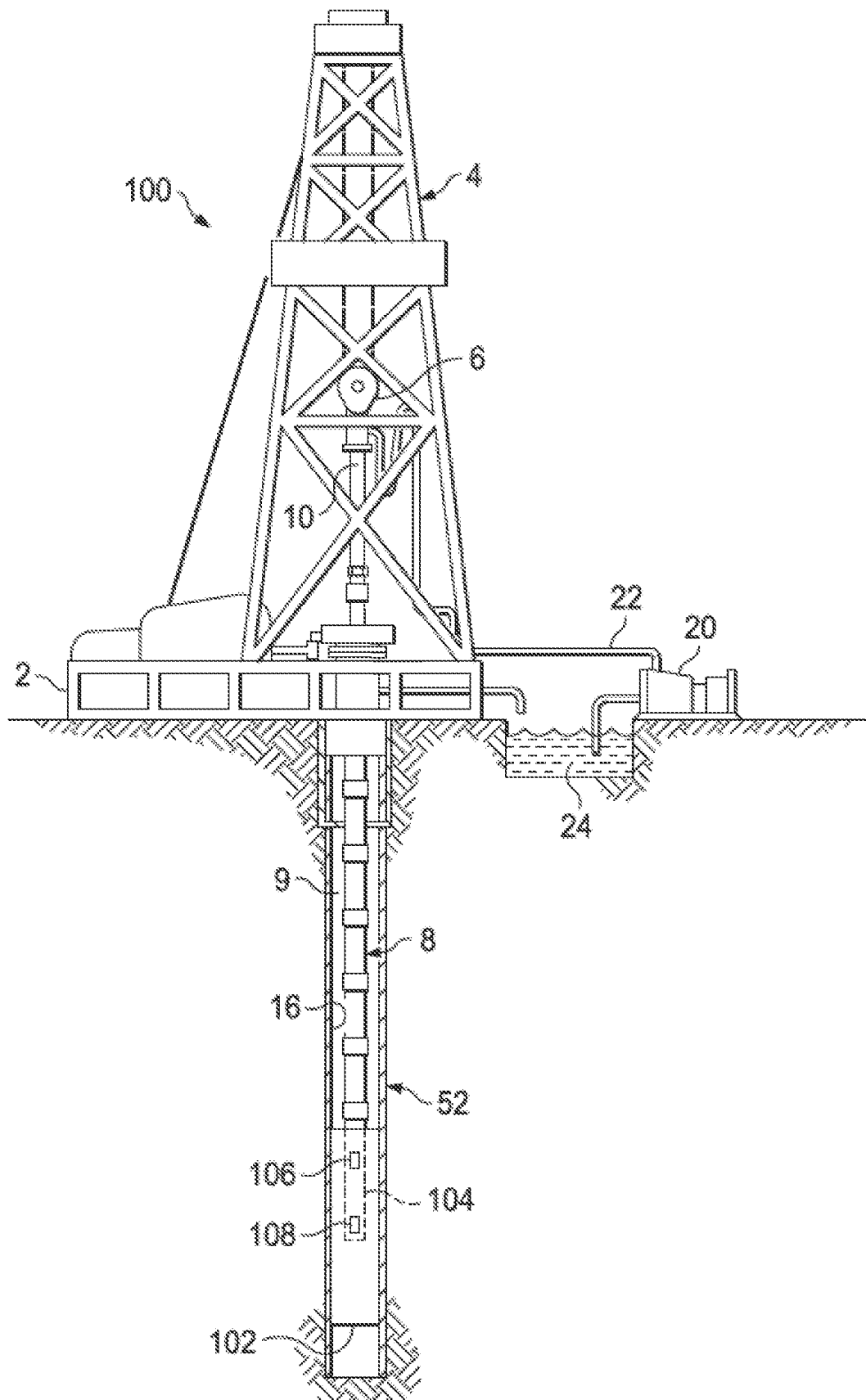


FIG. 1

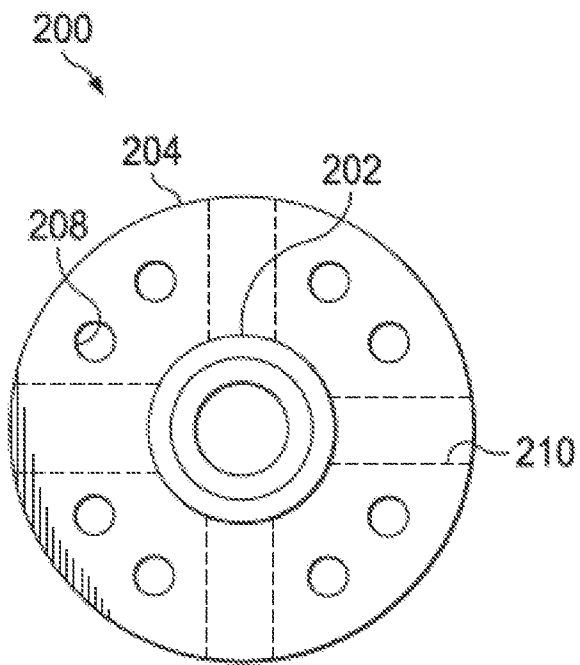


FIG. 2A

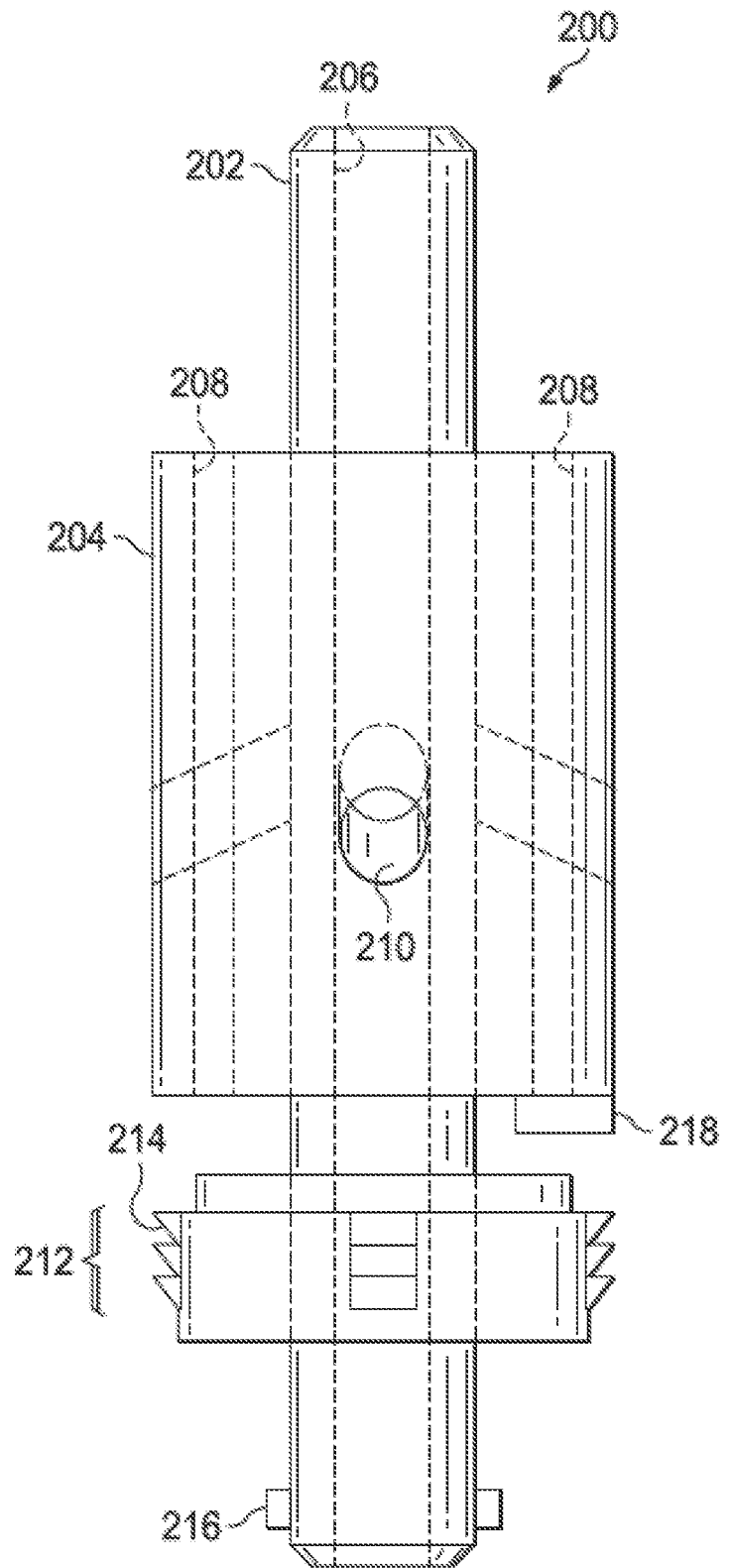


FIG. 2B

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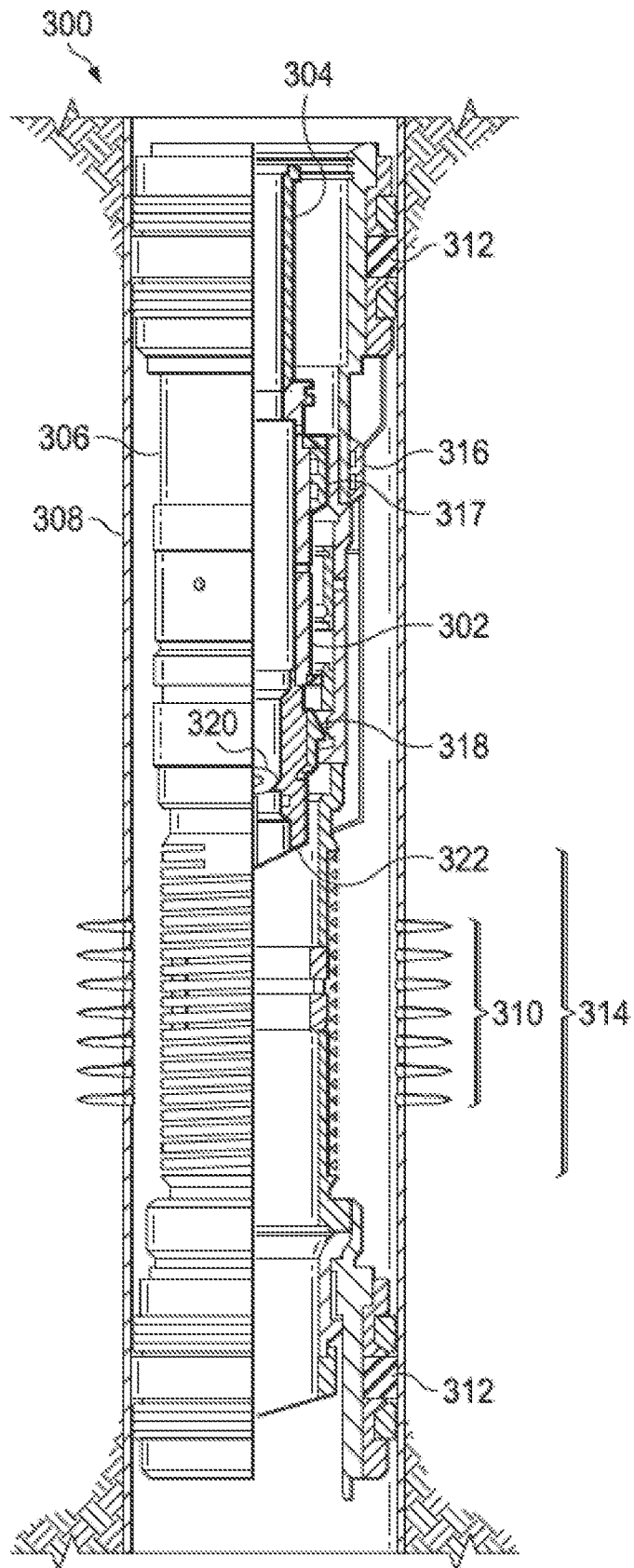


FIG. 3

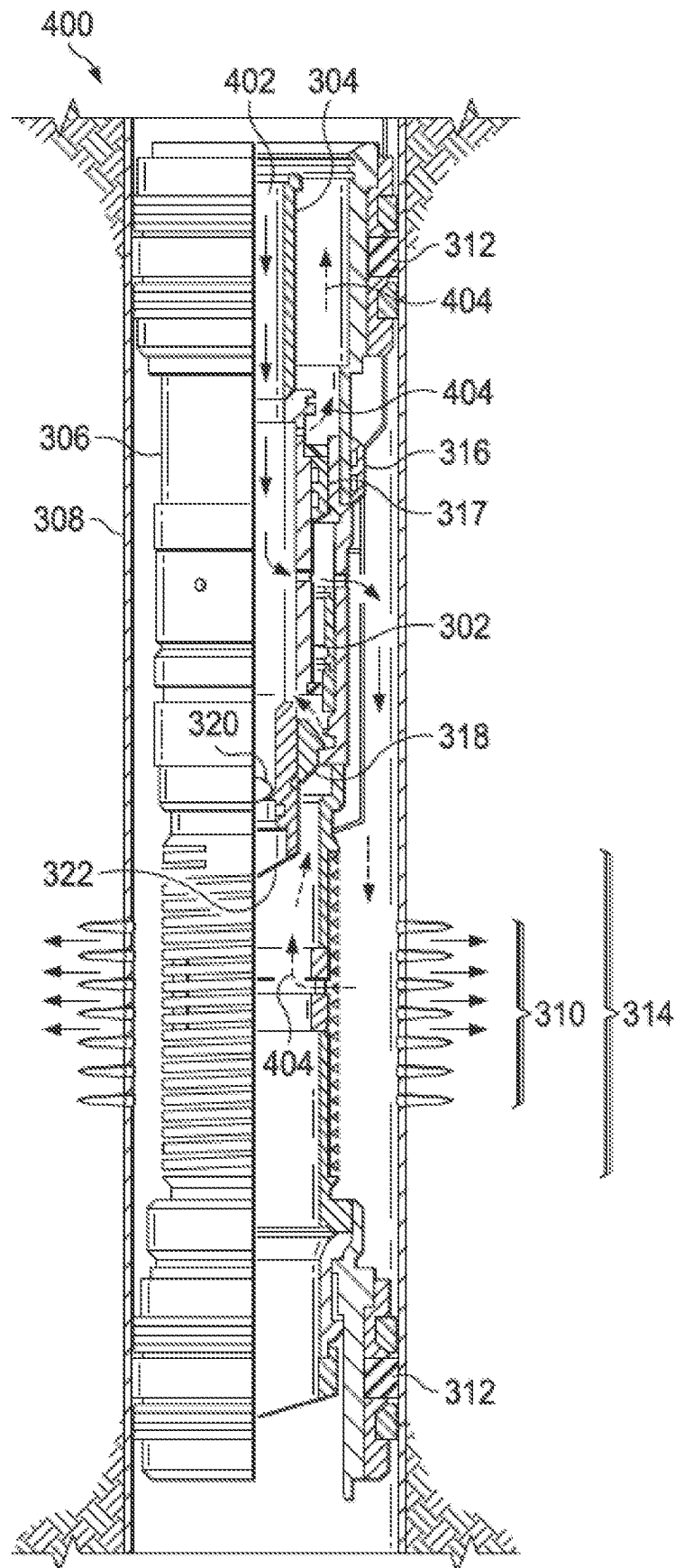


FIG. 4

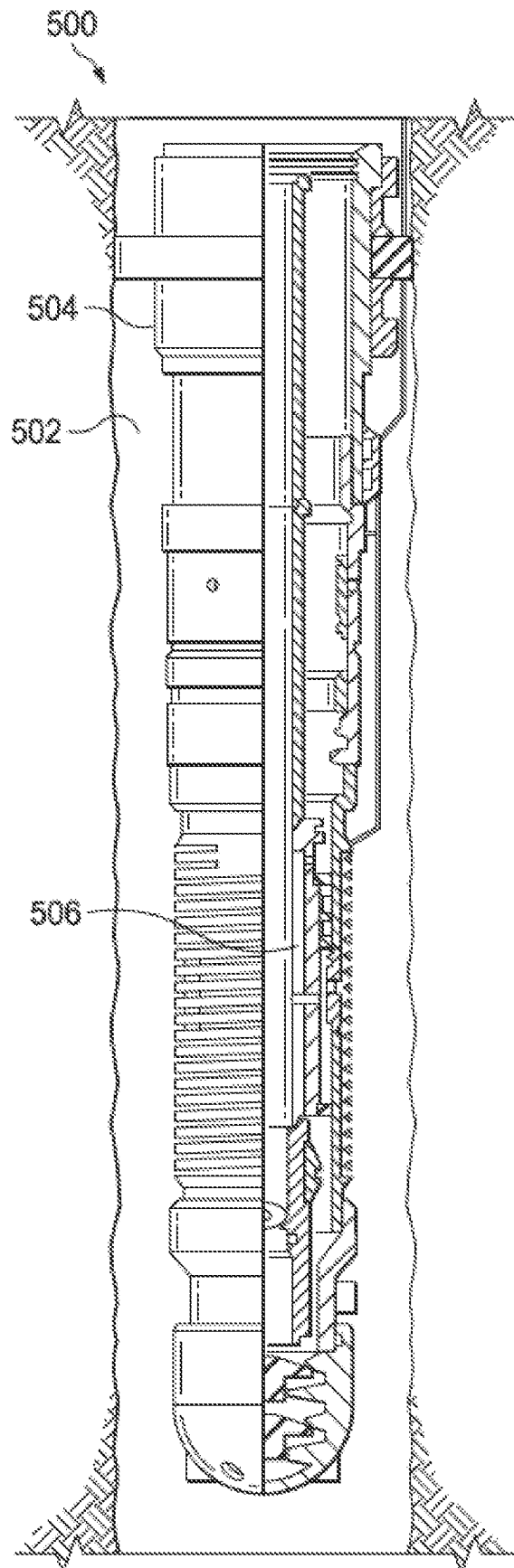


FIG. 5

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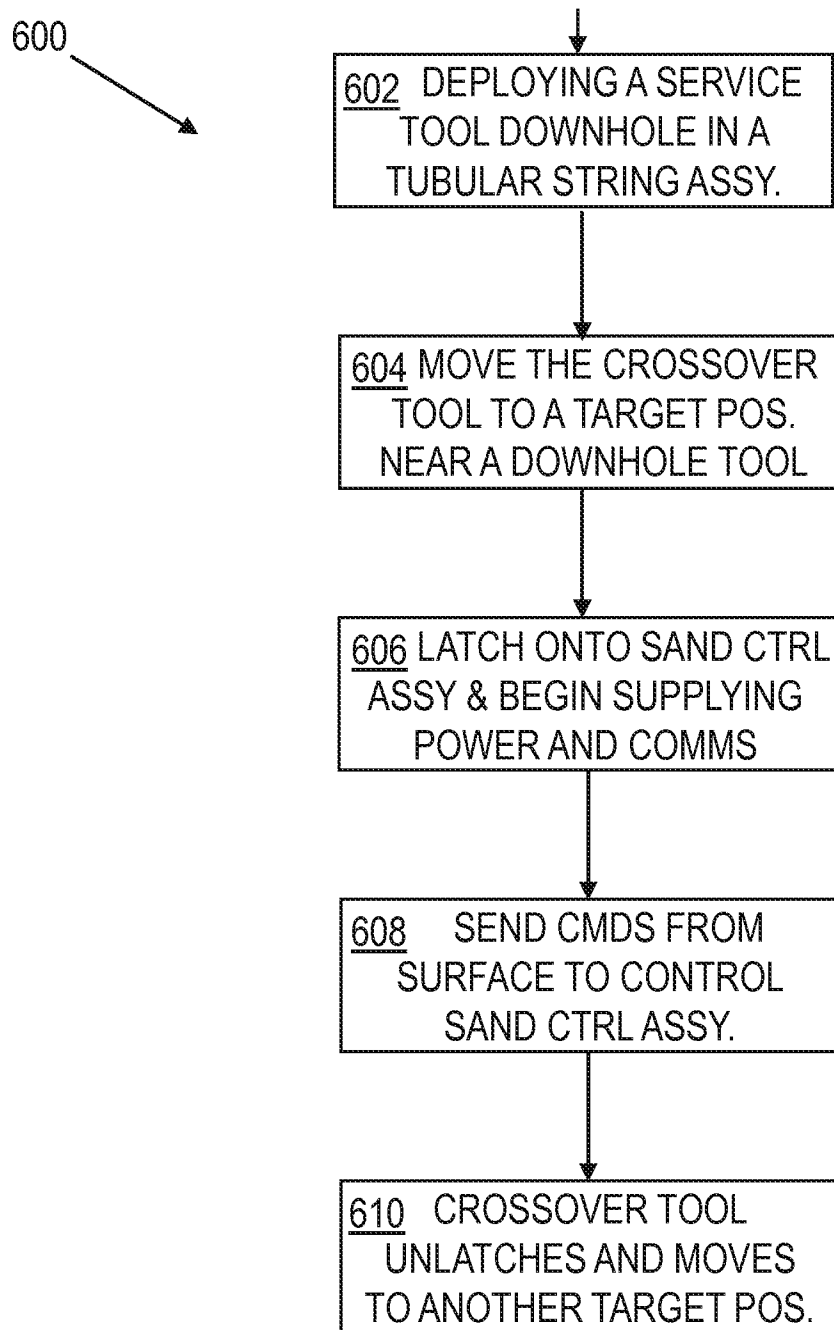


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/039117**A. CLASSIFICATION OF SUBJECT MATTER****E21B 41/00(2006.01)i, E21B 43/08(2006.01)i, E21B 33/12(2006.01)i, E21B 34/06(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 41/00; E21B 43/04; E21B 47/09; F17D 3/00; E21B 47/12; E21B 34/14; E21B 43/08; E21B 33/12; E21B 34/06

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: crossover, wellbore, subterranean, sand control assembly, electrically powered actuator and P/C coupler

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012-0090687 A1 (GRIGSBY et al.) 19 April 2012 See paragraphs [0011]-[0055] and figures 1-4F.	1,4-9
Y		2-3,10-21
Y	US 2015-0075767 A1 (BAKER HUGHES INCORPORATED) 19 March 2015 See paragraphs [0002]-[0008] and figures 13-16.	2-3,10-21
A	US 2009-0145603 A1 (CORONADO, MARTIN P.) 11 June 2009 See paragraphs [0001]-[0002], [0005]-[0008].	1-21
A	US 2003-0192694 A1 (ZACHMAN et al.) 16 October 2003 See paragraphs [0002]-[0007] and figures 1-11.	1-21
A	US 2015-0027701 A1 (PANAMARATHUPALAYAM et al.) 29 January 2015 See paragraphs [0015]-[0018] and figures 1A-2.	1-21



Further documents are listed in the continuation of Box C.



See patent family annex.

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