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Modular rotary steerable system

Abstract

A rotary steerable system including a steering section and a control section. The control section includes a modular control system that is field detachable from a remainder of the control section. The modular control system includes one or more modules that are field detachable from the other modules and a remainder of the modular control system. Examples of the modules of the modular control system include a power module configured to generate electrical power or electromagnetic field rotation from hydraulic power, a control module configured to control actuation of one or more pistons in the steering section, and/or a flow control module configured to selectively allow fluid flow into one or more distribution channels leading to the one or more pistons of the steering unit.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
1083004	12/1912	Davidson	N/A	N/A
4637479	12/1986	Leising	N/A	N/A
5186264	12/1992	Du Chaffaut	N/A	N/A
5265682	12/1992	Russell et al.	N/A	N/A
5332048	12/1993	Underwood	175/26	E21B 44/005
5520255	12/1995	Barr et al.	N/A	N/A
5553678	12/1995	Barr et al.	N/A	N/A
5582259	12/1995	Barr	N/A	N/A
5695015	12/1996	Barr et al.	N/A	N/A
5947213	12/1998	Angle	166/255.2	E21B 23/00
6089332	12/1999	Barr et al.	N/A	N/A
6158529	12/1999	Dorel	175/61	E21B 7/067
6467557	12/2001	Krueger et al.	N/A	N/A
7057316	12/2005	Spring	N/A	N/A
7133325	12/2005	Kotsonis et al.	N/A	N/A
7141901	12/2005	Spring	N/A	N/A
7378985	12/2007	Spring	N/A	N/A
7503405	12/2008	Hall et al.	N/A	N/A
8869916	12/2013	Clausen et al.	N/A	N/A
9016400	12/2014	Clausen et al.	N/A	N/A
9187956	12/2014	Hutton et al.	N/A	N/A
9624727	12/2016	Hutton	N/A	N/A
9869140	12/2017	Rushton	N/A	N/A
10655447	12/2019	Tilley	N/A	C09K 8/66
11326437	12/2021	Tchakarov	N/A	E21B 47/022
11913335	12/2023	Peters	N/A	E21B 7/06
11952894	12/2023	Bedouet	N/A	N/A
11970942	12/2023	Bedouet	N/A	N/A
2001/0042643	12/2000	Krueger et al.	N/A	N/A
2001/0052428	12/2000	Larronde	N/A	N/A
2002/0011358	12/2001	Wassell	N/A	N/A
2002/0112892	12/2001	Taylor	N/A	N/A
2005/0056421	12/2004	Homan et al.	N/A	N/A
2005/0109542	12/2004	Downton	N/A	N/A
2006/0243487	12/2005	Turner et al.	N/A	N/A
2006/0263215	12/2005	Sindt et al.	N/A	N/A
2012/0061148	12/2011	Clausen et al.	N/A	N/A

2012/0160565	12/2011	Downton	N/A	N/A
2013/0118812	12/2012	Clausen et al.	N/A	N/A
2014/0110178	12/2013	Savage et al.	N/A	N/A
2016/0002978	12/2015	Rushton	N/A	N/A
2018/0128060	12/2017	Haugvaldstad	N/A	N/A
2018/0202279	12/2017	Moriarty et al.	N/A	N/A
2020/0080381	12/2019	Hardin, Jr.	N/A	N/A
2020/0318437	12/2019	Gray	N/A	N/A
2020/0325731	12/2019	Chambers et al.	N/A	N/A
2021/0198949	12/2020	Haugvaldstad et al.	N/A	N/A
2022/0282571	12/2021	Bedouet	N/A	N/A
2025/0084703	12/2024	Bedouet	N/A	E21B 7/04

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
2547036	12/2005	CA	N/A
2170183	12/2006	CA	N/A
105239924	12/2015	CN	N/A
2426265	12/2005	GB	N/A
2002091553	12/2001	WO	N/A
2019190484	12/2018	WO	N/A
2020018816	12/2019	WO	N/A

OTHER PUBLICATIONS

International Search Report and Written Opinion, mailed Oct. 24, 2024, for corresponding International Patent Application No. PCT/US2024/042492. cited by applicant
Schlumberger, “NeoSteer CLx, Extreme curve and lateral at-bit steerable system,” 2019. cited by applicant
Schlumberger, “PowerDrive Orbit, Rotary steerable system,” 2016. cited by applicant
Scientific Drilling, Halo Technical Data Sheet, 2018. cited by applicant
Dexter Magnetic Technologies, Inc., “Final Report: Development of a High Pressure/High Temperature Don-hole Turbine Generator,” Oil & Natural Gas Technology, 2010. cited by applicant
D-Tech Rotary Steerable, “D-Tech RST—Engineered for Maximum Performance Through Superior Reliability,” 2020. cited by applicant
Halliburton, “iCruise® Intelligent Rotary Steerable System,” 2019. cited by applicant
Co-pending U.S. Appl. No. 17/682,127, filed Feb. 28, 2022, titled “Dual Piston Rotary Steerable System.” cited by applicant
Co-pending U.S. Appl. No. 17/682,503, filed Feb. 28, 2022, titled “Rotary Steerable System With Central Distribution Passages.” cited by applicant
Co-pending U.S. Appl. No. 18/463,795, filed Sep. 8, 2023, titled “Self-Contained Compact Rotary Steerable System.” cited by applicant
Application (including specification, drawings, and claims) from applicant's co-pending U.S. Appl. No. 18/463,795, filed Sep. 8, 2023, titled “Self-Contained Compact Rotary Steerable System.” cited by applicant

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Background/Summary

BACKGROUND

(1) In the process of drilling and producing oil and gas wells, rotary steerable systems are used to control and adjust the direction in which a well is drilled. Conventional rotary steerable systems are typically over 150 inches in length. These large systems require frequent maintenance. The conventional rotary steerable systems' long length presents challenges in the maintenance, including the need to transport the system from a drilling location to a shop for disassembly and repair.

Description

BRIEF DESCRIPTION OF THE DRAWING VIEWS

(1) FIG. **1** is a schematic view of the rotary steerable system of the present invention.

(2) FIG. **2** is a schematic view of a first configuration of a modular control system of the rotary steerable system.

(3) FIG. **3** is a schematic view of separated modules of the modular control system's first configuration.

(4) FIG. **4** is a schematic view of separated modules of a second configuration of the modular control system.

(5) FIG. **5** is a side view of one embodiment of the modular control system's second configuration.

(6) FIG. **6** is a side view of the modular control system in FIG. **5** assembled to fit within a control sleeve.

(7) FIG. **7** is a sectional view of one embodiment of the rotary steerable system including the modular control system in FIG. **5** disposed within the control sleeve.

(8) FIG. **8** is a schematic view of separated modules of a third configuration of a modular control system.

(9) FIG. **9** is a side view of one embodiment of the modular control system's third configuration.

(10) FIG. **10** is a side view of the embodiment of the modular control system shown in FIG. **9** assembled to fit within the control sleeve.

DETAILED DESCRIPTION OF SELECTED EMBODIMENTS

(11) Disclosed herein is a rotary steerable system including a modular control system. The modular control system is field detachable from the remainder of the rotary steerable system. The modular control system includes one or more modules that are each field detachable from the other modules and from the remainder of the rotary steerable system. As used herein, “field detachable” means that a system, module, unit, or part is connected to other parts with only mechanical connections that are easily detached without any tools or with only hand tools, and that the system, module, unit, or part has no electrical connections to any other system, module, unit, or part. As used herein, “modular” and “module” each means that a system, unit, or part is field detachable from all other systems, units, and parts.

(12) FIGS. **1-10** illustrate various configurations and embodiments of the rotary steerable system disclosed herein, with many other configurations and embodiments within the scope of the claims being readily apparent to skilled artisans after reviewing this disclosure.

(13) With reference to FIG. **1**, rotary steerable system **10** includes control section **12** and steering section **14**, each having a generally cylindrical shape. Steering section **14** may be configured to control and adjust the direction in which a well is drilled. As one skilled in the art will recognize, steering section **14** may include any mechanism for controlling and adjusting the direction in which a well is drilled. For example, steering section **14** may include actuating pistons **15** as described in

U.S. patent application Ser. No. 17/682,127, filed on Feb. 28, 2022, which is hereby incorporated by reference in its entirety. Control section **12** may be configured to selectively activate the actuating pistons **15** in steering section **14**. As used herein, "piston" means any structure configured to extend when activated in a radial direction from a tool to which it is secured or in which it is incorporated, including but not limited to a pad, a wedge arrangement, and a cam arrangement.

(14) Control section **12** includes control sleeve **16** and modular control system **18** disposed within cavity **20** of control sleeve **16**. Modular control system **18** is configured for rotation relative to control sleeve **16**. In one embodiment, modular control system **18** is configured to remain stationary with respect to a surrounding subterranean formation, such that control sleeve **16** rotates around modular control system **18**. In other words, modular control system **18** may be configured to remain geo-stationary. Lower end **21** of control sleeve **16** is secured to upper end **22** of steering housing **23** of steering section **14**. In this way, control sleeve **16** is rotationally secured to steering housing **23**. As used herein, "rotationally secured" means secured together such that two components rotate together (i.e., there is no relative rotation between two components under normal operating conditions).

(15) Referring again to FIG. **1**, modular control system **18** may be removably secured within cavity **20** of control sleeve **16** by an easily detachable mechanical connection. In some embodiments, modular control system **18** is removably secured within cavity **20** of control sleeve **16** by one or more fasteners. In the illustrated embodiment, fasteners **24** and **26** removably secure modular control system **18** within cavity **20** of control sleeve **16**. In some embodiments, fasteners **24** and **26** are rotationally secured to control sleeve **16**, while modular control system **18** rotates relative to fasteners **24** and **26**. Alternatively, fasteners **24** and **26** may be rotationally secured to modular control system **18**, with fasteners **24** and **26** rotating with modular control system **18** relative to control sleeve **16**. In other embodiments, fasteners **24** and **26** include one or more parts that are rotationally secured to modular control system **18** and one or more parts that are rotationally secured to control sleeve **16**. In still other embodiments, fasteners **24** and **26** may each include a mechanism secured to control sleeve **16** and a guide for stabilizing modular control system **18** as it rotates relative to control sleeve **16**. In order to remove modular control system **18** from control sleeve **16**, the user need only remove the one or more fasteners securing modular control system **18** to control sleeve **16** by using only a hand tool, such as a wrench. Once the fasteners are removed, modular control system **18** may then be entirely removed from control sleeve **16**. In this way, modular control system **18** is field detachable and modular.

(16) As shown in FIG. **2**, modular control system **18** may include one or more modules that are easily detached or removed from one another and from the other components of the rotary steerable system. In other words, the modules of modular control system **18** are field detachable. In the illustrated embodiment, modular control system **18** includes power module **28**, control module **30**, and flow control module **32**. In other embodiments, the modular control system may include any number of modules, such as between 1 and 10 modules, arranged in any order. For example, in the embodiment depicted in FIGS. **1-3**, power module **28** may be disposed upstream of control module **30**, and control module may be disposed upstream of flow control module **32**. In alternate embodiments, the power module may be disposed downstream of the control module.

(17) Power module **28** and control module **30** may be selectively connected at first connection **34**. First connection **34** may be defined by a downstream end of power module **28** and an upstream end of control module **30**. First connection **34** may be a mechanical connection. For example, first connection **34** may be a radial and thrust bearing connection. It may allow power module **28** to rotate relative to control module **30**. Power module **28** and control module **30** may be detached from one another by simply sliding the two modules apart without any tools. In this way, first connection **34** between power module **28** and control module **30** is field detachable and power module **28** is modular.

(18) Control module **30** and flow control module **32** may be selectively connected at second

connection **36**. Second connection **36** may be defined by a downstream end of control module **30** and an upstream end of flow control module **32**. Second connection **36** may be a mechanical connection. For example, second connection **36** may be a threaded connection, a shouldered cylinder-guided connection with a removable locking mechanism that prevents rotation and axial movement (e.g., a removable pin or set screw). Flow control module **32** may be detached from control module **30** using only hand tools, such as a wrench and vise.

(19) Flow control module **32** may be selectively connected to steering section **14** at third connection **37** (also shown in FIG. **1**). Third connection **37** may be defined by a downstream end of flow control module **32** and an upstream portion of steering section **14** (shown in FIG. **1**). Third connection **37** may be a mechanical connection. For example, third connection **37** may be formed by a flat surface contact between the downstream end of flow control module **32** and the upstream portion of steering section **14**. Alternatively, third connection **37** may be formed of any reciprocally shaped surfaces on downstream end of flow control module **32** and an upstream portion of steering section **14** that allow relative rotation between the two modules, such as reciprocal conical surfaces, reciprocal curved surfaces, or reciprocal cylindrical surfaces (i.e., a sliding cylinder contact). Flow control module **32** may be detached from steering section **14** by simply separating flow control module **32** from steering section **14** without any tools, such as by removing assembled modular control system **18** from control sleeve **16**.

(20) With reference to FIG. **3**, power module **28** may include power unit **38** and actuation unit **40**. Power unit **38** may be configured to provide power to rotary steerable system **10** by, for example, converting mechanical hydraulic power to electromagnetic field rotation and/or electrical power. In some embodiments, power unit **38** includes a turbine with an impeller or a positive displacement motor. Actuation unit **40** may be configured to actuate modular control system **18** by rotating modular control system **18** relative to control sleeve **16** or by adjusting the rotation rate of modular control system **18** relative to control sleeve **16**. In some embodiments, actuation unit **40** may include a magnetic brake or a contact brake (e.g., a clutch system). Actuation unit **40** may actuate modular control system **18** in response to rotation or power generated by power unit **38**.

(21) Referring again to FIG. **3**, control module **30** may include communication unit **42**, power supply unit **44**, control unit **46**, and navigation sensor unit **48**. Communication unit **42** may be configured to provide communication to and from the rotary steerable system. In other words, communication unit **42** may transmit messages to other tools within the wellbore, such as a measurement-while-drilling tool, and receive downlink messages from the surface. In certain embodiments, communication unit **42** may include an antenna or piezoelectric sensors and actuators for acoustic telemetry. Power supply unit **44** may be configured to power one or more units within control module **30** or other units within modular control system **18** without any physical electrical connections or wires between modules. In certain embodiments, power supply unit **44** may include a turbine or a positive displacement motor. Control unit **46** may be configured to adjust the position of modular control system **18** relative to steering section **14**, which in turn controls actuation of the pistons of steering section **14**. For example, control unit **46** may be configured to actuate power module **28** to orient a valve in a desired angular direction. Alternatively, control unit **46** may be configured to adjust an actuator in actuation unit **40** based on measurements taken by sensors in navigation sensor unit **48**. Navigation sensor unit **48** may be configured to detect an orientation of the rotary steerable system in a magnetic field or in a gravitational field relative to the surface. In certain embodiments, navigation sensor unit **48** may include a magnetometer for sensing a north-south direction, an accelerometer for sensing inclination, or a gyroscope for sensing rotation of the control unit relative to a surrounding subterranean formation.

(22) With reference still to FIG. **3**, flow control module **32** may include filter unit **50** and flow distribution unit **52**. Flow distribution unit **52** may be configured to divert a portion of the drilling fluid flowing through modular control system **18** into one or more distribution passages within

steering section **14** in order to actuate the pistons **15**. In some embodiments, flow distribution unit **52** may include any mechanism for selectively diverting fluid flow, such as a valve, a rotating valve segment, a flap, a sliding sleeve arrangement, or a rotating sleeve arrangement. Filter unit **50** may be configured to filter drilling fluid flowing therethrough, such as the drilling fluid diverted by flow distribution unit **52**. Filter unit **50** may include any combination of components configured to filter solid particles from drilling fluid or other fluid. In certain embodiments, filter unit **50** may include a filter formed of rings with shoulders such that the stacking of the rings creates small interstices that function to filter. In other embodiments, filter unit **50** may include a cylinder including slots, such as a one-piece cylinder including axially arranged slots.

(23) The units of each module of modular control system **18** may be configured in any order. For example, within control module **30**, navigation sensor unit **48** may be disposed upstream of control unit **46**, while the embodiment illustrated in FIG. **3** includes navigation sensor unit **48** disposed downstream of control unit **46**. Additionally, the units may be disposed within any of the modules of modular control system **18**. For example, actuation unit **40** may be disposed within power module **28** as illustrated in FIG. **3** or within the control module.

(24) FIG. **4** illustrates a second configuration of the modular control system. Modular control system **60** may include power module **62**, control module **64**, and flow control module **66**. Except as otherwise described, modular control system **60**, along with the modules and units contained therein, may have substantially the same features and functions as modular control system **18**. Power module **62** may include power unit **68** configured to generate electric power and/or electromagnetic field rotation. In the embodiment illustrated in FIGS. **5-7**, power unit **68** may include impeller **70** that is rotationally secured to power sleeve **71**. Impeller **70** may be sized and configured such that the outer ends of impeller **70** are closely proximate to an outer surface of cavity **20** in control sleeve **16** (as shown in FIG. **7**). As a drilling fluid flows through cavity **20** of control sleeve **16**, the drilling fluid flows through spaces in impeller **70**, thereby applying a rotational force on impeller **70** and power sleeve **71**. In this way, impeller **70** converts mechanical hydraulic power to electromagnetic field rotation.

(25) Control module **64** may include communication unit **72**, actuation unit **74**, power supply unit **76**, control unit **78**, and navigation sensor unit **80**. Communication unit **72** may be configured to provide communication to and from the rotary steerable system. In the embodiment illustrated in FIGS. **5-7**, communication unit **72** may include antenna **82** for transmitting measurement data and other data to a measurement-while-drilling (“MWD”) unit secured above the rotary steerable system, and the MWD unit may store the received data in a memory. Antenna **82** of the communication unit **72** may be formed of an electromagnetic antenna.

(26) In the embodiment illustrated in FIGS. **5-7**, actuation unit **74** disposed within control module **64** may include magnetic brake **84**, which functions as an actuator to apply rotational torque in a direction that is opposite to a rotational direction of control sleeve **16** and steering housing **23**. Magnetic brake **84** may apply rotational torque in response to the electromagnetic field rotation generated by impeller **70**. In this way, actuation unit **74** within control module **64** adjusts the rotation rate of modular control system **60** relative to control sleeve **16** in response to an electromagnetic signal from power unit **68** in power module **62** (i.e., without any electrical wires or any other physical electrical connections extending across the connection between the power module **62** and the control module **64**). In certain embodiments, magnetic brake **84** is the only actuator in the rotary steerable system.

(27) Power supply unit **76** may be configured to power one or more units within control module **30** or other units within modular control system **18**. Control unit **78** may be configured to adjust the position of modular control system **60** relative to steering section **14**, which in turn controls actuation of the pistons **15** of steering section **14**. For example, control unit **46** may be configured to adjust an actuator in actuation unit **40** based on measurements taken by sensors in navigation sensor unit **48**. Navigation sensor unit **80** may be configured to orient the rotary steerable system

relative to the surface. In the embodiment of FIGS. **5-7**, power supply unit **76**, control unit **78**, and navigation sensor unit **80** may be contained within control housing **86**. Navigation sensor unit **80** may include sensors disposed within control housing **86**. For example, navigation sensor unit **80** may include a magnetometer for sensing a north-south direction, an accelerometer for sensing inclination, and a gyrometer for sensing rotation of the modular control system relative to a surrounding subterranean formation. Control unit **78** within control housing **86** may be configured to adjust the magnetic brake **84** based on measurements taken by the navigation sensor unit **80**. Power supply unit **76** within control housing **86** may include batteries. In other embodiments, control module **64** includes no batteries and only a small amount of memory (e.g., flash memory only).

(28) Flow control module **66** may include filter unit **88**, flow distribution unit **90**, and housing **91**. Flow distribution unit **90** may be configured to divert a portion of the drilling fluid into the steering section **14** to actuate the pistons **15**, while filter unit **88** may be configured to filter the diverted fluid. In the embodiment shown in FIGS. **5-7**, filter unit **88** may include filter **92**, and flow distribution unit **90** may include valve rotor **94**. A portion of a drilling fluid flowing through cavity **20** of control sleeve **16** may flow through openings in filter **92**, through one or more openings in valve rotor **94**, and into one or more distribution passages leading to pistons **15**. Filter **92** may be formed of rings with shoulders such that the stacking of the rings creates small interstices that function to filter. Valve rotor **94** may cooperate with a valve stator **96** of the steering section **14** to actuate the pistons **15**. Valve rotor **94** rotates relative to the valve stator **96** as modular control system **60** rotates relative to control sleeve **16** and steering housing **23**.

(29) With the modules of modular control system **60** assembled as shown in FIGS. **6** and **7**, antenna **82** and magnetic brake **84** of control module **64** may be positioned within power sleeve **71** of power module **62**. This overlapping arrangement may form the first connection between power module **62** and control module **64**. Control housing **86** of control module **64** may be threadedly connected to housing **91** of flow control module **66**. This threaded connection may form the second connection between control module **64** and flow control module **66**. A flat surface of valve rotor **94** of flow control module **66** may engage a flat surface of valve stator **96** of steering section **14**. This sliding flat surface engagement may form the third connection between flow control module **66** and steering section **14**. The assembled modular control system **60** may be secured to control sleeve **16** by the mechanical connection of fasteners **24** and **26**, which engage control module **64** and power module **66**, respectively.

(30) Each of these connections is field detachable. The modular control system **60** may be detached from control sleeve **16** by disconnecting the fasteners **24** and **26** with hand tools only. Power module **62** may be easily detached from control module **64** by simply sliding the two modules apart. Control module **64** may be easily detached from flow control module **66** by unwinding the threaded connection with hand tools only, such as a wrench and vice. The third connection between flow control module **66** and steering section **14** may be easily detached by simply moving flow control module **66** away from steering section **14**. In this way, each of the power module **62**, control module **64**, and flow control module **66** are modular and field detachable.

(31) FIG. **8** illustrates a third configuration of the modular control system. Modular control system **100** may include power module **102**, control module **104**, and flow control module **106**. Except as otherwise described, modular control system **100**, along with the modules and units contained therein, may have substantially the same features and functions as modular control system **18** and modular control system **60**. In modular control system **100**, power module **102** is disposed between control module **104** and flow control module **106**. Control module **104** includes communication unit **108**, actuation unit **110**, power supply unit **112**, control unit **114**, and navigation sensor unit **116**. In the embodiment illustrated in FIGS. **9-10**, communication unit **108** may include antenna **118**, and actuation unit **110** may include magnetic brake **120**. Power supply unit **112**, control unit **114**, and navigation sensor unit **116** may be disposed within control housing **122**. Power module

102 of modular control system **100** includes power unit **123**, which includes impeller **124** in the embodiment illustrated in FIGS. **9-10**. Flow control module **106** of modular control system **100** may also include filter unit **126** and flow distribution unit **128**, which correspond to filter **130** and valve rotor **132** in the embodiment illustrated in FIGS. **9-10**, respectively.

(32) In this third configuration of the modular control system, the first connection between the control module **104** and the power module **102** may be formed of a radial and thrust bearing connection, which is easily detachable by simply sliding the two modules apart. The second connection between the power module **102** and flow control module **106** may be formed of a threaded connection or any other type of mechanical connection, which is easily detachable with hand tools.

(33) The modular control systems disclosed herein, including modular control systems **10**, **60**, and **100**, are easily detachable from the other parts of the rotary steerable system. Similarly, each module of the modular control system is easily detachable from the other modules and the other parts of the rotary steerable system. The modular control system and its parts are configured to be handled by a single user due to their size and weight. For example but not by way of limitation, the modular control system may weigh less than 50 lbs. Accordingly, the modular control system can be detached from the other parts of the rotary steerable system without using a lift assist device, such as a crane. Similarly, the modules of the modular control system may be separated from one another without using a lift assist device. The modular control system and its parts are configured to be detached from other parts with no tools or with only hand tools, such as wrenches and vices. No motor-assisted torque equipment, such as break-out machines, are required to detach the modular control system from other parts of the rotary steerable system. Similarly, no motor-assisted torque equipment, such as break-out machines, are required to detach the modules from other modules within the modular control system.

(34) The modularity of the modular control system is also supported by the mechanical nature of the connections among the separate modules and the connections between the modular control system and the remainder of the rotary steerable system. No electrical connections, such as electrical wires, extend across the connections between the modular control system and the remainder of the rotary steerable system. Similarly, no electrical connections extend across the connections between each module and the other modules of the modular control system. Accordingly, electrical connection manipulation or electrical wire manipulation is not required during the detachment process.

(35) These features allow users to easily detach the modular control system from the remainder of the rotary steerable system, and to easily separate the individual modules from one another, for easy removal at a drilling location. The lack of electrical wires or connections between modules and parts allows a user to detach the modules in a location other than a clean, dry location. The modules may be detached at a drilling location that may be wet and/or dirty without affecting electrical connections. In this way, the modular control system and its modules are field detachable. The modularity of the modular control system and its modules allows field replacement of the modular control system or individual modules as necessary to maintain the rotary steerable system between jobs or between drilling runs. It also reduces the number of complete back up tools required at the drilling location.

(36) As used herein, “upper” and “lower” are to be interpreted broadly to include “proximal” and “distal” such that the structures may not be positioned in a vertical arrangement. Additionally, the elements described as “upper” and “lower” may be reversed such that the structures may be configured in the opposite vertical arrangement. Except as otherwise described or illustrated, each of the components in this device has a generally cylindrical shape and may be formed of steel, another metal, or any other durable material. Portions of the rotary steerable system may be formed of a wear resistant material, such as tungsten carbide or ceramic coated steel.

(37) Each device described in this disclosure may include any combination of the described

components, features, and/or functions of each of the individual device embodiments. Each method described in this disclosure may include any combination of the described steps in any order, including the absence of certain described steps and combinations of steps used in separate embodiments. Any range of numeric values disclosed herein includes any subrange therein. “Plurality” means two or more. “Above” and “below” shall each be construed to mean upstream and downstream, such that the directional orientation of the device is not limited to a vertical arrangement.

(38) While preferred embodiments have been described, it is to be understood that the embodiments are illustrative only and that the scope of the invention is to be defined solely by the appended claims when accorded a full range of equivalents, many variations and modifications naturally occurring to those skilled in the art from a review hereof.

Claims

1. A rotary steerable system, comprising: a steering section; and a control section, wherein the control section comprises a control sleeve having an internal cavity extending therethrough, a control housing disposed within the cavity, and a modular control system partially disposed within the control housing, wherein the modular control system is field detachable from the control sleeve.
2. The rotary steerable system of claim 1, wherein the modular control system includes a power module configured to generate electrical power or electromagnetic field rotation from hydraulic power, wherein the power module is field detachable from a remainder of the modular control system.
3. The rotary steerable system of claim 2, wherein the power module includes a power unit configured to generate electrical power or electromagnetic field rotation from hydraulic power.
4. The rotary steerable system of claim 3, wherein the power module further includes an actuation unit configured to actuate one or more pistons in the steering section in response to the electrical power or electromagnetic field rotation generated by the power unit.
5. The rotary steerable system of claim 2, wherein the modular control system further includes a control module configured to control the actuation of one or more pistons in the steering section, wherein the control module is field detachable from the power module.
6. The rotary steerable system of claim 5, wherein the control module includes an actuation unit configured to control the actuation of the one or more pistons in response to an electromagnetic field signal received from the power module, wherein no electrical wires extend across a connection between the control module and the power module.
7. The rotary steerable system of claim 6, wherein the control module further includes a navigation sensor unit and a control unit, wherein the navigation sensor unit includes one or more sensors configured to detect an orientation or position of the rotary steerable system relative to a surface location, wherein the control unit is configured to adjust the actuation unit in response to measurements taken by one or more sensors of the navigation sensor unit.
8. The rotary steerable system of claim 7, wherein the control module further includes a power supply unit and a communication unit, wherein the power supply unit is configured to power one or more other units within the control module, and wherein the communication unit includes an antenna.
9. The rotary steerable system of claim 5, wherein the modular control system further includes a flow control module configured to selectively allow fluid flow into one or more distribution channels leading to the one or more pistons in the steering section, wherein the flow control module is field detachable from the control module.
10. The rotary steerable system of claim 9, the flow control module includes a filter unit and a flow distribution unit, wherein the filter unit is configured to filter a fluid flowing to the flow distribution unit, and wherein the flow distribution unit is configured to divert a portion of a fluid

flow to one or more distribution passages that lead to the one or more pistons in the steering section.

11. The rotary steerable system of claim 1 further comprising one or more fasteners, each of the one or more fasteners configured to removably secure the modular control system to the control sleeve.

12. The rotary steerable system of claim 1, wherein the modular control system comprises a plurality of modules, each module configured for detachable connection to one or more of the other modules.

13. A rotary steerable system, comprising: a steering section; and a control section, wherein the control section includes a control sleeve having an internal cavity extending therethrough, a control housing disposed within the cavity, and a modular control system partially disposed within the control housing, wherein the modular control system comprises at least one module, wherein the modular control system is field detachable from the control sleeve, and wherein the at least one module is field detachable from a remainder of the modular control system.

14. The rotary steerable system of claim 13, wherein the at least one module includes a power module configured to generate electrical power or electromagnetic field rotation from hydraulic power, wherein the power module is field detachable from the remainder of the modular control system.

15. The rotary steerable system of claim 14, wherein the power module includes a power unit configured to generate electrical power or electromagnetic field rotation from hydraulic power.

16. The rotary steerable system of claim 15, wherein the power module further includes an actuation unit configured to actuate one or more pistons in the steering section in response to the electrical power or electromagnetic field rotation generated by the power unit.

17. The rotary steerable system of claim 13, wherein the at least one module includes a control module configured to control actuation of one or more pistons in the steering section, wherein the control module is field detachable from the remainder of the modular control system.

18. The rotary steerable system of claim 17, wherein the control module includes an actuation unit configured to control the actuation of the one or more pistons in response to an electromagnetic field signal received from the power module, wherein no electrical wires extend across a connection between the control module and the power module.

19. The rotary steerable system of claim 18, wherein the control module further includes a navigation sensor unit and a control unit, wherein the navigation sensor unit includes one or more sensors configured to detect an orientation or position of the rotary steerable system relative to a surface location, wherein the control unit is configured to adjust the actuation unit in response to measurements taken by the one or more sensors of the navigation sensor unit.

20. The rotary steerable system of claim 19, wherein the control module further includes a power supply unit and a communication unit, wherein the power supply unit is configured to power one or more other units within the control module, and wherein the communication unit includes an antenna.

21. The rotary steerable system of claim 13, wherein the at least one module includes a flow control module configured to selectively allow fluid flow into one or more distribution channels leading to one or more pistons in the steering section, wherein the flow control module is field detachable from the remainder of the modular control system.

22. The rotary steerable system of claim 21, the flow control module includes a filter unit and a flow distribution unit, wherein the filter unit is configured to filter a fluid flowing to the flow distribution unit, and wherein the flow distribution unit is configured to divert a portion of a fluid flow to one or more distribution passages that lead to the one or more pistons in the steering section.