(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 June 2014 (26.06.2014)

(10) International Publication Number
WO 2014/100175 A1

(51) International Patent Classification:
E21B 44/02 (2006.01) *E21B 19/08* (2006.01)

(21) International Application Number:
PCT/US2013/076122

(22) International Filing Date:
18 December 2013 (18.12.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/718,662 18 December 2012 (18.12.2012) US

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,

[Continued on next page]

(54) Title: MONITORING AND CONTROL SYSTEMS FOR CONTINUOUS CIRCULATING DRILLING OPERATIONS

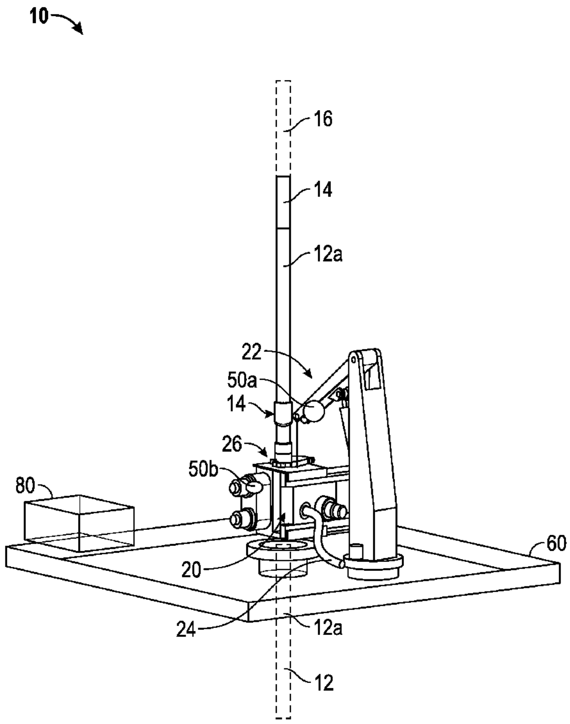

FIG. 1

(57) Abstract: An apparatus for continuously flowing drilling fluid along a drill string includes a continuous circulation device having at least a first fluid path in fluid communication with a top drive and a second fluid path in communication with a diverter. The diverter is in selective fluid communication with a pipe stand associated with the drills string. The apparatus also includes at least one sensor that estimates at least one operating parameter associated with the continuous circulation device. A related method includes using a continuous circulation device as described to manipulate the drill string and controlling the continuous circulation device using at least one sensor configured to estimate at least one operating parameter associated with the continuous circulation device.

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MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

TITLE: MONITORING AND CONTROL SYSTEMS FOR CONTINUOUS CIRCULATING DRILLING OPERATIONS

BACKGROUND OF THE DISCLOSURE

1. Field of the Disclosure

[0001] This disclosure relates generally to devices, systems, and methods to maintain constant fluid circulation during the drilling of a borehole.

2. Background of the Art

[0002] During drilling of boreholes, drilling fluids may be used to stabilize the borehole, cool and lubricate drilling equipment, and to apply a desired pressure to a formation being drilled. During drilling, the drilling fluid is circulated continuously. Conventionally, when a new section of drill pipe is connected to or disconnected from the top of a drill string, the circulation of drilling fluid is stopped. When circulation stops, the drilling fluid may settle and increase in viscosity. Thus, the drilling fluid circulation pumps may have to overcome a pressure increase to re-start circulation. Moreover, some formations may have relatively narrow margins between fracturing gradient and pore pressure. Maintaining pressure on the formation within these margins may be challenging during interruptions in drilling fluid circulation.

[0003] The present disclosure addresses the need for providing continuous fluid circulation during interruptions in drilling.

SUMMARY OF THE DISCLOSURE

[0004] In one aspect, the present disclosure provides an apparatus for continuously flowing drilling fluid along a drill string that is being manipulated. The apparatus may include a continuous circulation device having at least a first fluid path in fluid communication with a top drive and a second fluid path in communication with a diverter. The diverter is in selective fluid communication with a pipe stand associated with the drills string. The apparatus also includes at least one sensor that estimates at least one operating parameter associated with the continuous circulation device.

[0005] In another aspect, the present disclosure provides a method for using a continuous circulation device. The method may include using the continuous circulating device to manipulate the drill string and controlling the continuous circulation device using at least one sensor configured to estimate at least one operating parameter associated with the continuous circulation device.

[0006] Examples of certain features of the disclosure have been summarized rather broadly in order that the detailed description thereof that follows may be better understood and in order that the contributions they represent to the art may be appreciated. There are, of course, additional features of the disclosure that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For a detailed understanding of the present disclosure, reference should be made to the following detailed description of the embodiments, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals, wherein:

FIG. 1 isometrically illustrates a continuous circulation system that uses valves interconnected with drill stands in accordance with one embodiment of the present disclosure;

FIG. 2 sectionally illustrates a valve control device and a valve made in accordance with one embodiment of the present disclosure;

FIG. 3 sectionally illustrates a continuous circulation system that uses a circulation sub in accordance with one embodiment of the present disclosure;

FIGS. 4a-c schematically illustrate a drill string manipulated by a top drive during use of a continuous circulation system in accordance with one embodiment of the present disclosure;

FIG. 5 illustrates in block-diagram format an automated continuous circulation system in accordance with one embodiment of the present disclosure; and

FIG. 6 schematically illustrates a fluid control device that can selectively switch fluid flow between the top drive and the diverter in accordance with one embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0001] The present disclosure provides continuous circulation systems that measure one or more operating parameters to safely and efficiently manipulate the drill string; *e.g.*, add drill pipe to or remove drill pipe from a drill string. In certain embodiments, the operating parameters may include environmental and / or position information. This information may be used to ensure that fluid connections are made-up or broken only when pressures are within prescribed ranges and moving components are in their proper alignment. Illustrative embodiments according to the present disclosure are described below.

[0002] Referring to **Fig. 1**, there is shown one embodiment of a continuous circulation system **10** (CCS **10**) according to the present disclosure for manipulating drill string while maintaining drill mud circulation. The CCS **10** includes a fluid circuit that includes at least two fluid paths that may be used to circulate drilling mud along a drill string **12**. The CCS **10** can selectively switch fluid flow between these two fluid paths to maintain continuous fluid circulation in the drill string **12** as pipe stands **12a** are added to or removed from the drill string **12**. The drill string **12** may be formed of pipe stands **12a**. Each pipe stand **12a** may be formed of multiple pipe joints. The pipe stands **12a** are interconnected by valves **14**. A top drive **16**, (not shown), may be used to rotate and displace the drill string **12** in a wellbore (not shown). The top drive **16** is configured in a conventional manner to direct fluid into the uppermost end of the drill string **12**. The fluid path via the top drive **16** is the primary fluid path into the drill string **12**. The valves **14** are part of the second fluid path into the drill string **12**.

[0003] In one embodiment, the system **10** may use a diverter to bypass the top drive **16** and pump fluid directly into the drill string **12**. The diverter may be a valve control device **20** that is moved by an arm **22**. A fluid line **24** connects a source (not shown) for drilling fluid to a circulation adapter (**Fig. 2**) associated with the valve control device **20**. The circulation adapter can selectively supply the valve **14** with pressurized drilling fluid while the top drive and a pipe stand **12a** are disconnected.

[0004] Referring to **Fig. 2**, there is shown a valve control device **20** that is operatively engaging the valve **14**. As shown, the top drive **16** has drilled the drill string **12** into the wellbore (not shown) to a point that another pipe stand must be added to the drill string **12** for continued drilling. The valve **14** includes an upper end **28** and a lower end **30**. The valve **14** may be fitted with flow control devices that allow fluid communication to the lower end **30** via either the upper end **28** or a lateral opening. In one embodiment, the valve **14** may include an upper circulation valve **32**, a lower circulation valve **34**, and an inlet **36**. The upper circulation valve **32** selectively blocks flow along the bore **38** connecting the upper and lower ends **28**, **30**. The lower circulation valve **34** selectively blocks flow between the bore **38** and the inlet **36**. The valve control device **20** includes an upper valve actuator **39a** that can shift the upper circulation valve **32** between an open and a closed position and a lower valve actuator **39b** that can shift the lower circulation valve **34** between an open and a closed position. It should be appreciated that the CCS **10** has two separate fluid paths that can independently circulate drilling fluid into the drill string **12**, which then flows into the wellbore (not shown). The first fluid path is formed when the upper circulation valve **32** is open and the lower circulation valve **34** is closed. In this flow path, drilling fluid flows along the bore **38** from the upper end **28** to the lower end **30**. The second fluid path is formed when the upper circulation valve **32** is closed and the lower circulation valve **34** is open. In this flow path, the drilling fluid flows along from the line **24** (**Fig. 1**), across the inlet **36**, into the bore **38**, and down to the lower end **30**.

[0005] The CCS **10** may include sensors or instruments that provide information relating to one or more operating parameters relating to the internal conditions of the CCS **10**. This information may be used by human operators to ensure that making up and breaking pipe connections occurs only under pre-determined conditions; *e.g.*, below a specified pressure or flow rate. Alternatively, a programmable controller may use this information to partially or fully automate the operation of the CCS **10**. Illustrative sensors for obtaining operating parameter information are discussed below.

[0006] To monitor the environmental conditions of equipment such as the valves **32**, **34**, the system may include one or more pressure sensors **40a-c**. For example, a pressure sensor **40a** may be used to sense a pressure at the inlet **36**, a pressure sensor **40b** may be used to sense a pressure along the bore **38** at a location between the upper circulation valve **32** and the upper end **28**, and a pressure sensor **40c** may be used to sense a pressure along the bore **38** at a location between the lower circulation valve **34** and the lower end **30**. In one embodiment, the pressure sensors **40b,c** may be embedded in a body **15** of the valve **14**. The embedded pressure sensors **40b,c** may transmit data and /or power using an inductive coupling. Alternatively, the embedded pressure sensors **40b,c** may include data conductors (not shown) that include terminals (not shown) on accessible outer surface of the body **15**. Suitable pressure sensors include, but are not limited to, pressure transducers, piezoelectric devices, electromagnetic devices, capacitive devices, potentiometric devices, etc.

[0007] To monitor the position of equipment, the system **10** may include one or more position sensors **50a-f**. As used herein, the term "position" refers to a relative position between two or more objects, an absolute position relative to a reference frame, an alignment, a location, or an orientation. Illustrative position sensors include, but are not limited to linear position sensors, rotational position, contact sensors, acoustic sensors, LVDT-type sensors, and inductive proximity sensors. In certain arrangements, the system may include a position sensor **50a** (**Fig. 1**) to determine the position of the arm **22** (**Fig. 1**), position sensor **50b** (**Fig. 1**) to determine the position of the valve control device **20**, position sensor **50c** to determine the position of the circulation adapter **26**, position sensors **50d,e** may be used to determine the position of the valve actuators **39a**, **39b**, and position sensor **50**f may be used to determine the position of the valve **14**. It should be understood that the identified positions sensors **50a-f** are merely illustrative in nature and that position sensors may be used in connection with other devices associated with the CCS **10**.

[0008] Referring now to **Figs. 1** and **2**, in one illustrative mode of operation, a system such as the top drive **16** may be used to progress the drill string **12** into the wellbore until the valve **14** is proximate to the drill floor **60**. This step in the operation is illustrated in **Fig. 2** wherein the top drive **16** is shown as positioned just above the valve control device **20**. Next, the arm **22** moves the valve control device **20** into engagement with the valve **14**. This engagement may involve the interaction between several components of valve control device **20** and the valve **14**. For example, the valve inlet **36** is aligned with the circulation adapter **26**, the upper circulation valve **32** is operatively connected to an upper valve actuator **39a**, and the lower circulation valve **34** is operatively connected to a lower valve actuator **39b**. The position sensors **50**a-f may be used to verify that these moving components and connections are properly aligned with one another.

[0009] During the above-described process, drilling fluid is still circulated through the top drive **16** and along the valve **14** via the upper end **28**. The pressure associated with this flow may be sensed by the pressure sensor **40b**. Next, the circulation adapter **26** is inserted into a side inlet **36** in the valve **20**. After the fluid line **24** is pressurized with drilling mud, the lower valve actuator **39b** actuates the lower circulation valve **32** to the open position, e.g., by axial or rotational motion. The pressure sensor **40**a may be used to determine when the pressure in the fluid line **24** is sufficiently high to actuate the lower circulation valve **32**. Now, drilling fluid may flow through the side inlet **36** into the bore **38**. At this point, drilling fluid is circulated through the top drive **16** and through the valve control unit **20** and side inlet **36**.

[0010] To hydraulically isolate fluid flow from the top drive **16**, the upper valve actuator **39a** actuates the upper circulation valve **32**. The upper circulation valve **32** hydraulically seals the upper end **28** from the lower end **30**. Thus, drilling fluid circulates only through the side inlet **36**. The pressure sensors **40a** and **40c** may be used to ensure that the drilling mud is circulating properly.

[0011] The bore **38** uphole of the upper circulation valve **32** is now depressurized. The pressure sensor **40b** may be used to monitor this depressurizing and identify when the pressure has sufficiently dropped to a point where the valve **14** may be decoupled from the top drive **16**.

[0012] After the top drive **16** is disconnected from the valve **14**, a new joint or stand of drill pipe **12a**, which also has a valve at one end, is connected to the drill string **12** and the top drive **16** is connected to the valve of the new pipe stand **12a** as generally shown in **Fig. 1**. At this stage, a pressure above the valve **14** and the upper circulation valve **32** through the top drive **16** is re-established. The upper valve actuator **39a** actuates the upper circulation valve **32** to an open position and the lower circulation valve **34** is closed using the lower valve actuator **39b**. Again, the pressure sensor **40b** may be used to monitor the pressure in the bore **38** and determine when the pressure is sufficiently high to open the upper circulation valve **32**. The pressure sensor **40a** may be used to monitor the pressure at the inlet **36** and determine when the pressure is sufficiently high to close the lower circulation valve **34**. Then, the circulation through the fluid line **24** is stopped. After the pressure sensor **40**a indicates that the pressure in line **24** is below a desired value, the circulation adapter **26** may be disconnected from the inlet **36** and the valve actuators **39a**, **39b** may be decoupled from their respective valves **32**, **34**. At this point, the valve control device **20** may be moved away from the drill string.

[0013] It should be appreciated that the position sensors **50a-f** may be used to ensure that the moving components of the system **10** properly align with one another and also with the valve **14** during the above-described operation. That is, prior to or after the mechanical interactions described above (e.g., axial or rotational movement, physical connections / disconnections, fluid connections / disconnections), these position sensors **40a-c** may provide information as to whether a particular component device is positioned as intended.

[0014] In some embodiments, the information obtained by the pressure sensors **40a-c** and the position sensors **50a-f** may be transmitted to a controller **80**. The controller **80** may display the pressure and / or position information to a human operator. In other embodiments, the controller **80** may include one or more processes and memory modules that include algorithms and programs for semi-automated or fully automated operation. For example, the controller **80** may use the information from the pressure sensors **40a-c** and position sensors **50a-f**, as well as other information relating to the system **10**, to automatically add pipe to or remove pipe from the drill string **12**.

[0015] It should be understood that the teachings of the present disclosure are not limited to any particular continuous circulation system. While **Figs. 1** and **2** illustrate a continuous circulation system that used valves positioned between pipe stands, other continuous circulation systems do not use such valves. Nevertheless, the present teachings may be readily applied to such systems as discussed below.

[0016] **Fig. 3** illustrates another continuous circulation system **100** (CCS **100**) for maintaining a continuous flow of drilling fluid in a drill string **12** that is manipulated in some manner. The drill string **12** is shown connected to a top drive **16** at a pin-box connection **12b.** As before, the drill string **12** is formed of pipe stands **12a**, which also use similar pin-box connections.

[0017] In one embodiment, the system may include a diverter that can selectively bypass the top drive **16** and flow drilling fluid directly into the drill string **12**. The diverter may be a circulation sub **102** ("sub **102**") that surrounds and encloses a portion of the drill string **12**. The sub **102** includes upper and lower seals **110**, **112**, upper and lower anchors **120**, **122**, upper and lower chambers **130**, **132**, and an intermediate isolator valve **140**. The sub **102** includes fluid passages **150**, **152** that provide selective fluid communication with the upper and lower chambers **130**, **132** respectively. Thus the CCS **100** also has two fluid paths for flow fluid to the drill string **12**. A first path is through the top drive **16**. The second path is through the fluid passages **150**, **152** of the sub **102**.

[0018] The upper seal **110** is disposed at an upper opening **159** of the sub **102** and the lower seal **112** is disposed at a lower opening **162** in the body **12**. The seal material is selected to enable a seal at working pressure despite variances in a diameter of the drill string **12**. Moreover, the seals **110**, **112** are configured to allow movement of the drill string **12**, both axially and rotationally, while the seal is formed.

[0019] The upper locking anchor **120** is arranged below the upper seal **110** and the lower locking anchor **122** is arranged above the lower seal **112**. The locking anchors **120**, **122** are arranged to allow free axial movement of the drill string **12** when in the collapsed position. When the locking anchors **120**, **122** are activated, the pin end **12**c of the drill string **12a** lands on and cannot pass through the upper locking member **120** and the box end **12**d of the drill string **12a** lands on and cannot pass through the lower locking member **122**.

[0020] The upper pressure chamber **130** is formed between the upper locking anchor **120** and the isolator valve **140**. The lower pressure chamber **132** is formed between the lower locking anchor **122** and the isolator valve **140**. The isolator valve **140** is configured to selectively hydraulically isolate the upper chamber **130** from the lower chamber **132**. Further, the valve **140** is configured to be radially retractable in order to allow passage of the drill string **12**.

[0021] To monitor the environmental conditions of equipment inside the CCS **100**, the system may include one or more pressure sensors **160a-b**. For example, a pressure sensor **160**a may sense pressure at the upper chamber **130** and a pressure sensor **160**b may sense pressure at the lower chamber **132**. These pressure sensors **160a,b** may be used to ensure that the upper and lower chambers **130**,**132** are at a prescribed pressure (*e.g.*, atmospheric pressure (~15 psi / 1 bar)) before depressurizing either of the sealing elements **110**, **112**. Also, these pressure sensors may provide an indication that the upper and lower chambers **130**, **132** are at substantially equal pressure before opening valve **140**. Other environmental sensors may include flow sensors **161a-b**. For example, a flow sensor **161a** may be used to estimate a fluid flow rate along the fluid port **150** and a flow rate sensor **161b** may be used to estimate a flow rate along the fluid port **152**. Along with flow sensors located elsewhere at the rig or in the wellbore, these environmental sensors can also provide information indicative of out-of-norm conditions, such as drilling fluid losses (lost circulation) and formation fluid influx (kick or blowout).

[0022] To monitor the position of equipment, the CCS **100** may include one or more position sensors **170a-c**. For example, a position sensor **170a** may provide an indication of the position of the top drive **16** and a position sensor **170b** may provide an indication of the position of the lower pipe stand **12a**. Further, a position sensor **170c** may be used to determine the position of the pin-box connection **12b**. These position sensors **170a-c** may be used to determine the position of the top drive **16** and drill stands **12a** relative to the sub **102** and / or one another within the chambers **130**, **132**.

[0023] Referring now to **Figs. 3** and **4A-C**, in an illustrative mode of operation, the CCS **100** is initially in a neutral position where the seals and valves are open and thereby minimally restrict the movement of the drill string **12** along the sub **102**. The top drive **16** drives the drill string **12** downward toward the drill rig floor (not shown) until the pin-box connection is inside the sub **102**. The information provided by the position sensors **170a-c** may be used during this positioning process. Next, slips (not shown) may be used to engage and secure the drill string **12** to prevent axial movement. The sub **102** may be moved or shifted as needed to allow access for pipe handling devices such as an iron roughneck, rig tongs, and other torque tools. The pipe handling tools may be used to loosen and partially disconnect the pin-box connection **12b**. Thereafter, the pipe handling tool device may be moved away and the sub **102** may be moved such that the pin-box connection **12b** is just below the valve **140** as shown in **Fig. 4A**. Again, the position sensors **170a-c** may be used during this positioning step. Now, the locking anchors **120,122** may be engaged and the seal elements **110,112** may be pressurized to hydraulically isolate the chambers **130,132**. The pin-box connection **12b** may be completely disconnected.

[0024] To begin diverting drilling mud, drilling mud is pumped into the lower chamber **132** via the fluid port **152** while drilling mud is still circulating through top drive **16** and the drill string **12**. The top drive **16** is raised above the valve **140** and the fluid circulation is gradually transferred from the top drive **16** to fluid port **152** until there is no flow through top drive **16**. During redirection of fluid flow, the pressure sensors **160a,b** and the flow sensor **161b** may be used to ensure that the switch-over of flow is proceeding as intended. The valve **140** may be actuated to a closed position, which hydraulically isolates the upper chamber **130** from the lower chamber **132** as shown in **Fig. 4B**. The pressure in the upper chamber **130** may be bled off by draining off the resident drilling fluid via the port **150**.

[0025] Once the sensor information indicates that the pressure in the upper chamber **130** is below a specified level, the upper locking mechanism **120** and the upper seal **110** may be actuated to an open position and the top drive **16** may be extracted from the sub **102**. A new pipe stand may be connected to the top drive **16** and lowered into the upper chamber **130**. As before, the position sensors **170a-c** may be used during this positioning activity. The upper locking mechanism **120** and the upper seal **110** may be re-activated to seal the upper chamber **130**. The upper chamber **130** may be filled with drilling fluid until the pressure sensors **160a,b** indicate that there is substantially equal pressure between the upper and lower chambers **130** and **132**. The valve **140** may be opened and the two pipe stands **12a** may be connected to one another as shown in **Fig. 4C**. The upper and lower drill pipes **12a** can be rotated to screw together to form the pin-box connection **12b**. As drill pipe connection is being made up, fluid flow is gradually transferred from the fluid port **152** to the top drive **16** until there is no flow through the fluid port **152**. Pressure may be bled off from the chambers **130**, **132**. After the environmental sensors **160a,b**, and **161a,b** indicate that pressure is below specified levels, the upper and lower locking mechanisms **120**, **122** and the upper and lower seals **110**, **112** may be deactivated.

[0026] The sub **102** may be raised to allow access for the pipe handling devices to apply a final torque to pin-box connection **12b**. Finally, the slips (not shown) may be deactivated to release the drill string **12** and the sub **102** may be moved to a neutral position. Now, the drilling may continue.

[0027] Referring now to **Fig. 5**, there is shown one embodiment of a system **200** that includes a controller **240** programmed to control operations using environmental and position measurements. The system **200** may include a fluid control device **210** that receives fluid from a rig drilling fluid circulation system **220** and directs the drilling fluid to either or both of the top drive **16** or a diverter **230** (*e.g.*, the valve control device **20** of **Fig. 1** or the sub **102** of **Fig. 3**). In embodiments, the controller **240** may include processors with resident memory modules programmed with algorithms and instructions to make-up and break pipe connections according to preset sequence and only under specified conditions. For example, the controller **240** may be programmed to not deactivate the sealing elements **110**, **112** (**Fig. 3**) if the pressure is above a preset value (*e.g.*, greater than 15 psi) in either or both the upper and lower chambers **130**, **132** (**Fig. 3**). The system may also include fluid diverters that safely divert high pressure spikes away from personnel.

[0028] Referring to **Fig. 6**, there is shown one embodiment of a fluid control device **210** that can selectively switch fluid flow between the top drive **16** (**Fig. 1-3**) and the diverter **230** (**Fig. 5**). The fluid control device **210** may be a Y-joint type of dual choke that receives a fluid flow from a fluid source such as a mud pump splits flow into two or more fluid paths. The fluid control device **210** may include an inlet **262**, a top drive outlet **264** and a diverter outlet **266**. Each of the outlets **264**, **266** may include adjustable flow restriction elements **270** such as restrictor plates that can vary flow parameter such as flow rates in response to control signals. Referring to **Figs. 5** and **6**, the controller **240** may be programmed to control the flow restriction elements **270** and thereby divert a precise percentage of the drilling fluid flow to either one or both fluid paths: *i.e.*, the top drive **16** and / or the diverter **230**. The fluid control device **210** may also include additional flow paths that may be used to vent or otherwise direct fluid; *e.g.*, from the top drive **16** or the fluid passages **150**, **152** (**Fig. 3**) of the sub **102** (**Fig. 3**).

[0029] It should be appreciated that the positions of these sensors are merely illustrative of the locations they may be positioned to acquire information useful to the operation of the systems **10**, **100**, and **200**. Similarly, the types and locations of the environmental sensors are merely illustrative of the types of sensors and locations that may be used in the operation of the CCS **10**, **100**.

[0030] The top drive **16** is only a one non-limiting type of drill string control system that may be used to rotate and / or move the drill string **12**.

[0031] While the foregoing disclosure is directed to the one mode embodiments of the disclosure, various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope of the appended claims be embraced by the foregoing disclosure.

THE CLAIMS

We Claim:

1. An apparatus for continuously flowing drilling fluid along a drill string, comprising:

   - a continuous circulation device having at least a first fluid path in fluid communication with a top drive and a second fluid path in communication with a diverter in selective fluid communication with a pipe stand associated with the drills string; and

   - at least one sensor configured to estimate at least one operating parameter associated with the continuous circulation device.

2. The apparatus of claim 1, at least one operating parameter relates to at least one of: (i) pressure, (ii) flow rate, and (iii) position.

3. The apparatus of claim 1, wherein the continuous circulation device includes at least one sealing element configured to form a hydraulically isolated chamber in which at least a portion of the drill string is enclosed, and wherein the at least one sensor estimates at least one of: (i) a pressure, and (ii) a flow rate in the hydraulically isolated chamber.

4. The apparatus of claim 1, further comprising a valve in which at least a portion of the first fluid path and the second fluid path are formed, wherein the valve includes an upper circulation valve that selectively closes the first fluid path and a lower circulation valve that selectively closes the second fluid path.

5. The apparatus of claim 4, wherein the at least one sensor includes a first sensor in pressure communication with the first fluid path and a second sensor in pressure communication with the second fluid path.

6. The apparatus of claim 5, wherein the first and the second sensor are embedded in the valve.

7. The apparatus of claim 6, further comprising a fluid circulation device configured to convey a drilling fluid through the fluid conduit.

8. The apparatus of claim 1, wherein the continuous circulation system includes a circulation sub configured to selectively isolate at least a portion of the pipe stand, the circulation sub including:

- an upper hydraulic chamber;
- an upper port in selective fluid communication with the upper hydraulic chamber;
- a lower hydraulic chamber; and
- a lower port in selective fluid communication with the lower hydraulic chamber.

9. The apparatus of claim 8, wherein the at least one sensor includes a pressure sensor in pressure communication with at least one of: (i) the upper hydraulic chamber, and (ii) the lower hydraulic chamber; and a flow rate sensor in fluid communication with at least one of (i) the upper port, and (ii) the lower port.

10. A method for continuous flowing drilling fluid along a drill string, comprising:

- manipulating the drill string using a continuous circulation device having at least a first fluid path in fluid communication with a top drive and a second fluid path in communication with a diverter in selective fluid communication with a pipe stand associated with the drill string; and

- controlling the continuous circulation device using at least one sensor configured to estimate at least one operating parameter associated with the continuous circulation device.

11. The method of claim 10, at least one operating parameter relates to at least one of: (i) pressure, (ii) flow rate, and (iii) position.

12. The method of claim 10, wherein the continuous circulation device includes at least one sealing element configured to form a hydraulically isolated chamber in which at least a portion of the drill string is enclosed, and further comprising using the at least one sensor to estimate at least one of: (i) a pressure, and (ii) a flow rate in the hydraulically isolated chamber.

13. The method of claim 10, wherein at least a portion of the first fluid path and the second fluid path are formed in a valve, wherein the valve includes an upper circulation valve that selectively closes the first fluid path and a lower circulation valve that selectively closes the second fluid path.

14. The method of claim 13, wherein the at least one sensor includes a first sensor in pressure communication with the first fluid path and a second sensor in pressure communication with the second fluid path.

15. The method of claim 14, wherein the first and the second sensor are embedded in the valve.

16. The method of claim 15, further comprising conveying a drilling fluid through the fluid conduit using a fluid circulation device.

17. The method of claim 10, wherein the continuous circulation system includes a circulation sub configured to selectively isolate at least a portion of the pipe stand, the circulation sub including:

- an upper hydraulic chamber;

- an upper port in selective fluid communication with the upper hydraulic chamber;

- a lower hydraulic chamber; and

- a lower port in selective fluid communication with the lower hydraulic chamber.

18. The method of claim 17, wherein the at least one sensor includes a pressure sensor in pressure communication with at least one of: (i) the upper hydraulic chamber, and (ii) the lower hydraulic chamber; and a flow rate sensor in fluid communication with at least one of (i) the upper port, and (ii) the lower port.

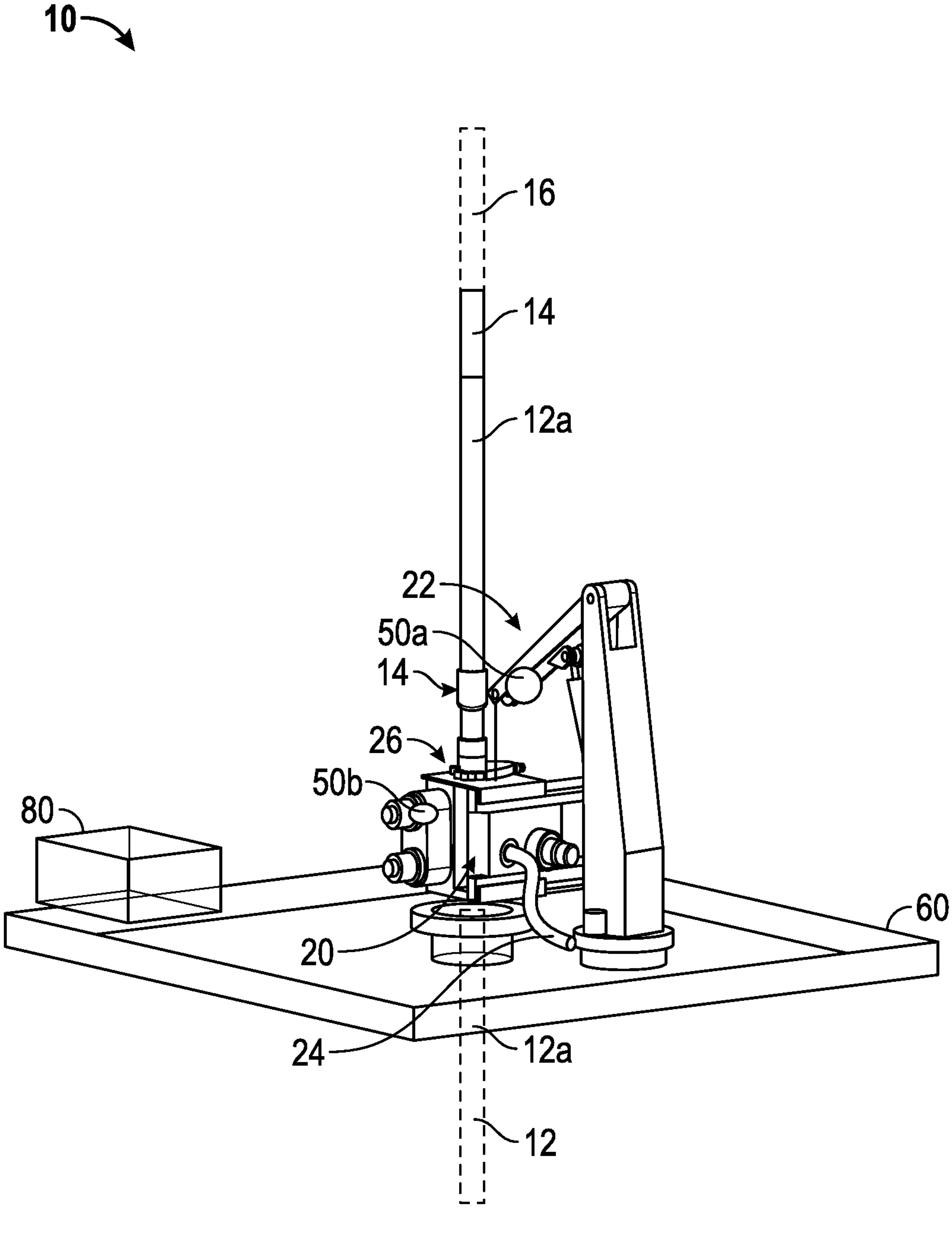
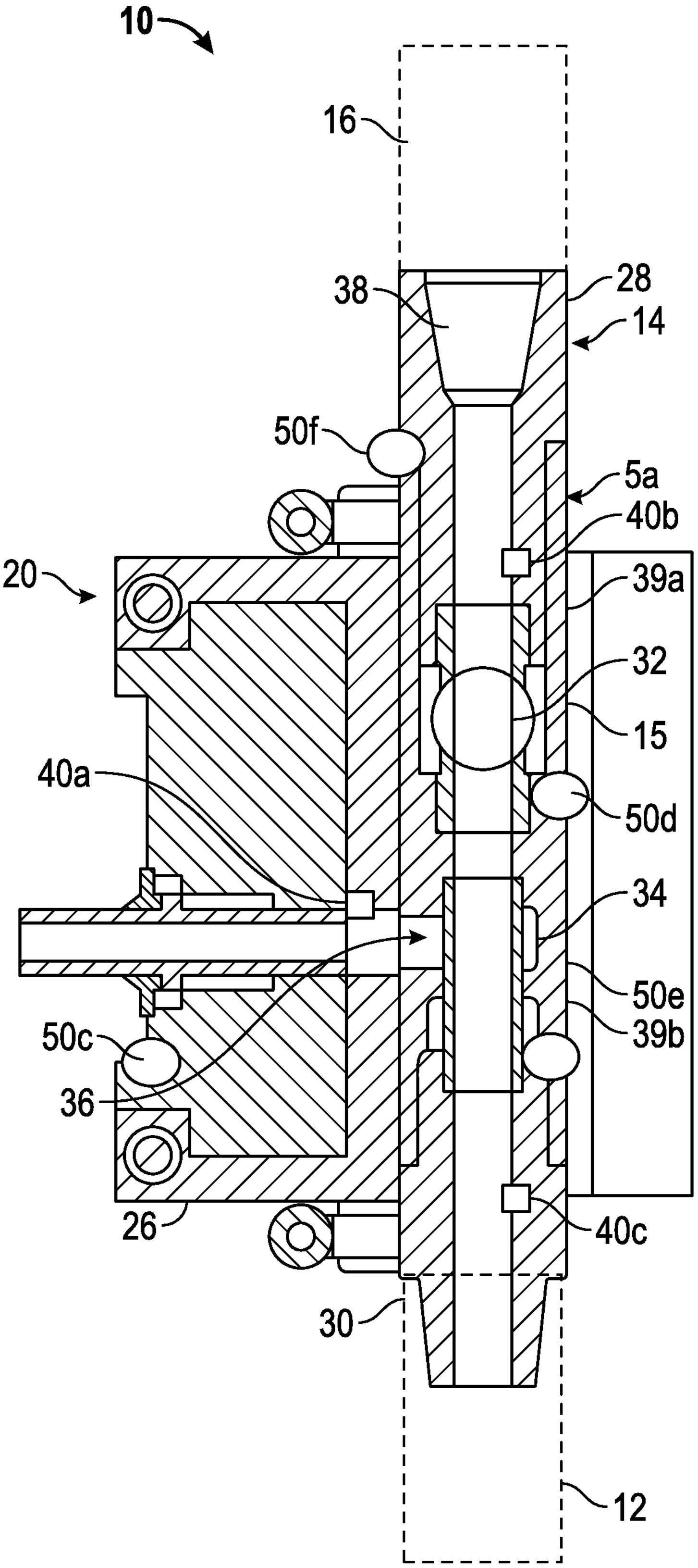


FIG. 1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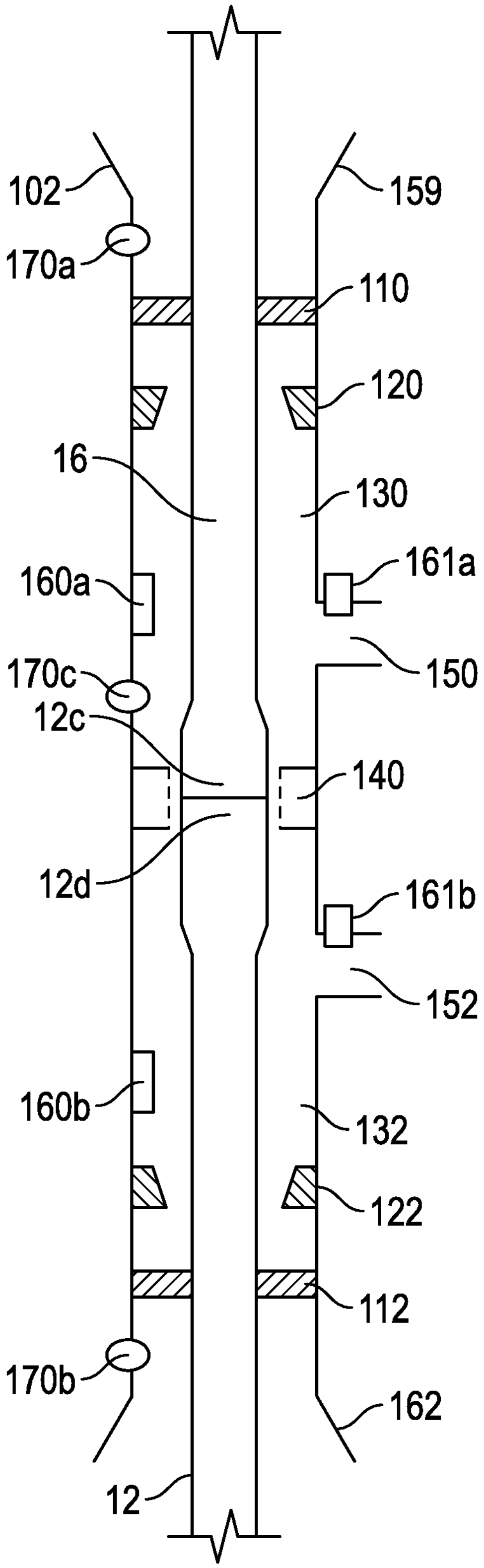
26
40c
30
12

FIG. 2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170b
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FIG. 3

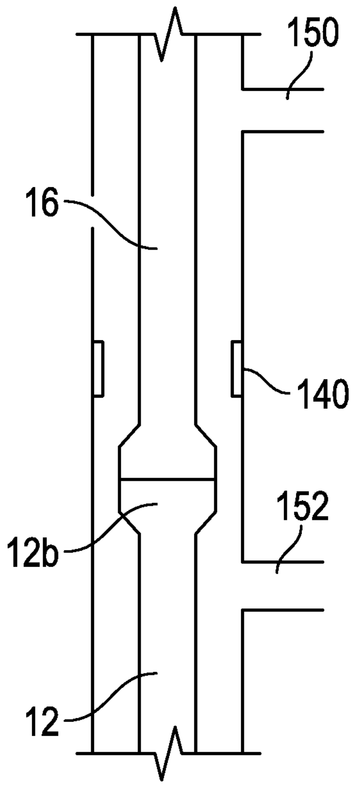

FIG. 4A

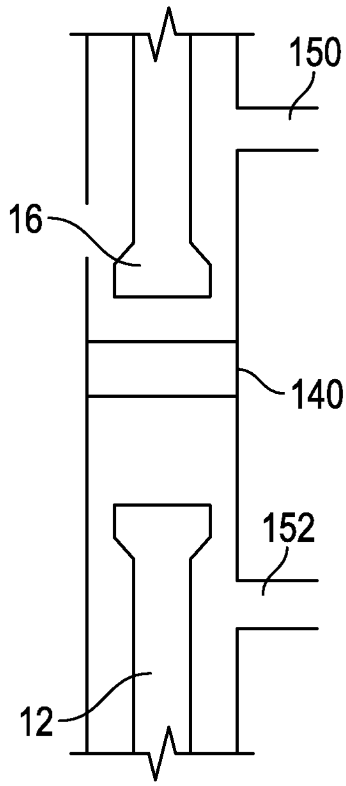

FIG. 4B

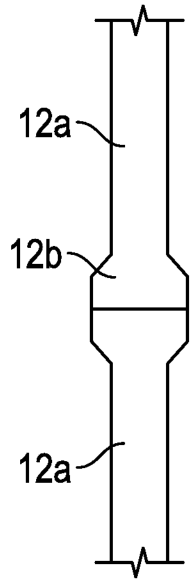

FIG. 4C

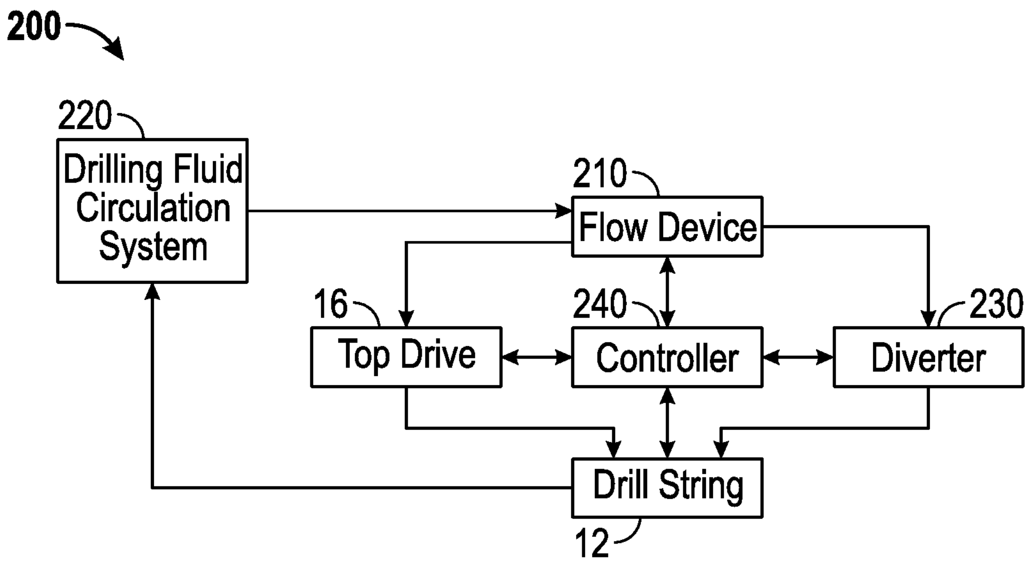

FIG. 5

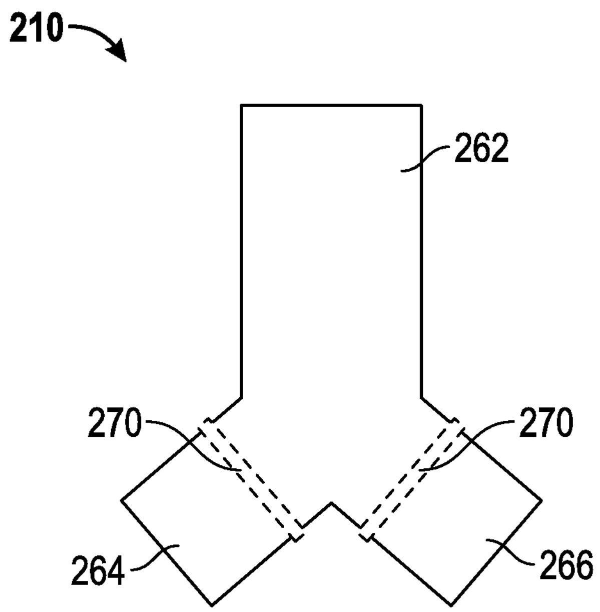

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/076122

A. CLASSIFICATION OF SUBJECT MATTER

E21B 44/02(2006.01)i, E21B 19/08(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 44/02; E21B 3/02; E21B 21/00; E21B 21/10; E21B 21/08; F16K 15/18; B25B 17/00; E21B 19/08

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: circulation, continuous, pump, fluid, diverter, top-drive and sensor

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2003-0221519 A1 (HAUGEN, DAVID M.) 04 December 2003 See paragrsphs [0016]-[0019],[0065]-[0077]; claims 1-2; and figure 1.	1-18
Y	US 2008-0060846 A1 (BELCHER et al.) 13 March 2008 See paragraphs [0030],[0054]-[0129] and claims 1,19.	1-18
A	US 2010-0252272 A1 (HAUGHOM, PER OLAV) 07 October 2010 See paragraphs [0046]-[0050] and figure 3.	1-18
A	US 2010-0200299 A1 (VATNE, PER A.) 12 August 2010 See claims 10,18 and figure 3.	1-18
A	WO 2012-006457 A1 (NATIONAL OILWELL VARCO L.P.) 12 January 2012 See claims 1,22 and figure 2.	1-18

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search
09 April 2014 (09.04.2014)

Date of mailing of the international search report
09 April 2014 (09.04.2014)

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