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(71) Applicant: **HALLIBURTON ENERGY SERVICES, INC.** [US/US]; 3000 N. Sam Houston Parkway E., Houston, Texas 77032-3219 (US).

(72) Inventor: **LEE, Shao Hwa**; Block 9H, Yuan Ching Road, #10-84, Singapore 618650 (SG).

(74) Agents: **KAISER, Iona** et al.; McDermott Will & Emery LLP, 500 North Capitol Street, N.W., Washington, District of Columbia 20001 (US).

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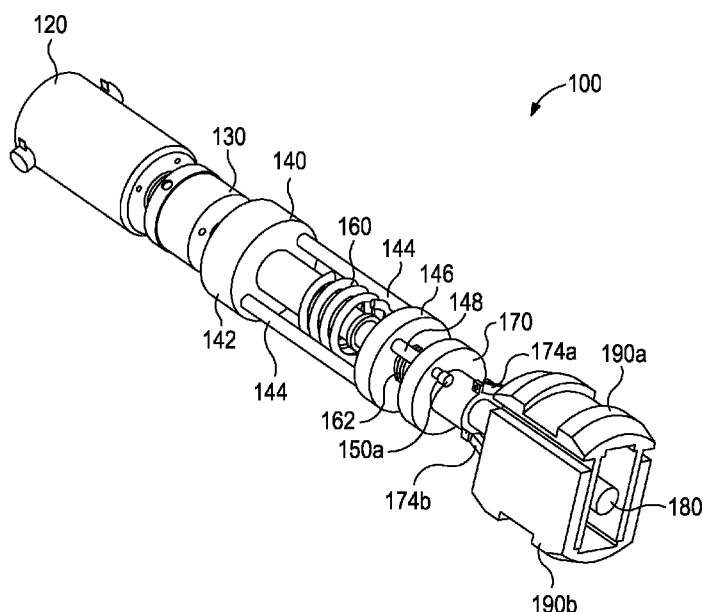


FIG. 2C

(57) Abstract: Disclosed are shifting tools for opening and closing shifting sleeves. A disclosed completion system includes a completion string having a shifting sleeve movably arranged therein, a service tool configured to be arranged at least partially within the completion string and including a shifting tool having one or more shifting keys configured to mate with the shifting profile. When the shifting keys locate and mate with the shifting profile, an axial load applied on the service tool axially moves the shifting sleeve. If the shifting key is misaligned with a complementary shape of the shifting sleeve, a lower detent housing retracts toward an upper detent housing against a force of a detent spring to allow the shifting keys to retract while maintaining a radially outward force. If an axial load is removed, the housings are automatically retracted by a return spring, causing the shifting keys to disengage.

ELECTROMECHANICAL SHIFTING TOOL

BACKGROUND

- 5 **[0001]** Various types of well tools commonly used in oil and/or gas well production strings include sliding or shifting members that are required to be selectively actuated. For example, sliding sleeve valves generally include a sleeve, which is selectively shifted to open or close ports to provide communication from or shut off communication between the bore of a production string and the well annulus.
- 10 **[0002]** In some applications, particulate materials such as sand and other wellbore debris are produced to the surface during the extraction of hydrocarbons from a well that traverses unconsolidated or loosely consolidated subterranean formations. To prevent the production of such particulate material to the surface, unconsolidated or loosely consolidated production intervals in the well are often gravel packed. In a typical gravel pack operation, a completion string including a packer, a circulation valve, a fluid loss control device and one or more sand control screens, is lowered into the wellbore to a position proximate the desired production interval. A service tool is then positioned within the completion string and a fluid slurry that includes a liquid carrier and a particulate material (*i.e.*, gravel) is then pumped through the circulation valve and into the well annulus formed between the sand control screens and the perforated well casing or open hole production zone. The liquid carrier either flows into the adjacent formation or returns to the surface by flowing through the sand control screens, or both. In either case, the gravel is deposited around the sand control screens to form a gravel pack, which is highly permeable to the flow of hydrocarbon fluids but simultaneously blocks the flow of particulate materials often suspended in the hydrocarbon fluids. As such, gravel packs can successfully prevent the problems associated with the production of particulate materials from the formation.
- 25 **[0003]** During the gravel packing operation, the service tool is often moved between various positions with respect to the completion string. For instance, the service tool typically has one or more shifting tools that can be used to move sliding sleeves associated with the completion string between open and closed configurations. Opening a circulating sleeve arranged in the circulation valve, for example, may expose one or more corresponding
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circulation ports that place the interior of the service tool in fluid communication with an annulus defined between the completion string and an adjacent formation. Upon removing the service tool from the completion string, it is often required to move various sleeves to their corresponding closed positions.

- 5 **[0004]** Some shifting tools traditionally operate based on hydraulic systems that utilize a "normally open" solenoid as a failsafe measure. Hydraulic systems can be expensive to build and maintain. Moreover, during use, heat and high pressure conditions in hydraulic systems can present safety hazards.

10 **BRIEF DESCRIPTION OF THE DRAWINGS**

- [0005]** The following figures are included to illustrate certain aspects of the present disclosure, and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modifications, alterations, combinations, and equivalents in form and function, without
15 departing from the scope of this disclosure.

[0006] FIG. 1 illustrates an exemplary completion system that may employ the principles of the present disclosure, according to one or more embodiments.

- [0007]** FIG. 2A illustrates a perspective view of an exemplary shifting
20 tool, according to one or more embodiments.

[0008] FIG. 2B illustrates a plan view of an exemplary shifting tool, according to one or more embodiments.

[0009] FIG. 2C illustrates a perspective view of an exemplary shifting tool, according to one or more embodiments.

- 25 **[0010]** FIG. 2D illustrates a plan view of an exemplary shifting tool, according to one or more embodiments.

[0011] FIG. 3A illustrates a cross-sectional side view of an exemplary shifting tool in a retracted configuration, according to one or more embodiments.

- [0012]** FIG. 3B illustrates a cross-sectional side view of an exemplary
30 shifting tool in an actuated configuration partially contacting a shifting sleeve, according to one or more embodiments.

[0013] FIG. 3C illustrates a cross-sectional side view of an exemplary shifting tool in an actuated configuration engaged to a shifting sleeve, according to one or more embodiments.

[0014] FIG. 3D illustrates a cross-sectional side view of an exemplary shifting tool in a retracted configuration, according to one or more embodiments.

[0015] FIG. 4A illustrates a cross-sectional side view of an exemplary shifting tool in a retracted configuration, according to one or more embodiments.

5 **[0016]** FIG. 4B illustrates a cross-sectional side view of an exemplary shifting tool in an actuated configuration, according to one or more embodiments.

DETAILED DESCRIPTION

10 **[0017]** The present disclosure relates to the treatment of subterranean production intervals and, more particularly, to shifting tools and shifting sleeves that can be opened and closed by the shifting tools.

[0018] The shifting tools disclosed herein allow an operator to controllably open and close shifting sleeves during a run-in into a wellbore. The
15 shifting keys can be compliant to properly engage a shifting profile of the shifting sleeve. A detent spring allows upper and lower detent housings to move relative to each other and be biased away from each other to allow a limited range of radial movement by the shifting keys, as they attempt to align with the profile of the shifting sleeve. The shifting tool can automatically retract the keys to allow
20 the shifting tool to be removed during power shutdown. Advantageously, such automatic release can be achieved without requiring power to drive the motor backwards, thereby removing the need for a backup battery that would otherwise reside onboard the shifting tool. Furthermore, a return spring biases at least one of the upper detent housing and the lower detent housing to a
25 retracted position that is automatically achieved when the motor ceases its operations.

[0019] Referring to FIG. 1, illustrated is an exemplary completion system 1 that may employ the principles of the present disclosure, according to one or more embodiments. As illustrated, the system 10 may include a
30 completion string 2 that may be coupled to a work string 4 configured to extend longitudinally within a wellbore 6. The wellbore 6 may penetrate multiple subterranean formation zones 8a, 8b, and 8c, and the completion string 2 may be extended into the wellbore 6 until being arranged or otherwise disposed generally adjacent the formation zones 8a-c. The formation zones 8a-c may be
35 portions of a common subterranean formation or hydrocarbon-bearing reservoir.

Alternatively, one or more of the formation zones 8a-c may be portion(s) of separate subterranean formations or hydrocarbon-bearing reservoirs. The term "zone" as used herein, however, is not limited to one type of rock formation or type, but may include several types, without departing from the scope of the disclosure.

[0020] The completion string 2 may be deployed within the wellbore 6 and used to hydraulically fracture and gravel pack the various formation zones 8a-c, and subsequently regulate hydrocarbon production from each production interval or formation zone 8a-c. Although only three formation zones 8a-c are depicted in FIG. 1, it will be appreciated that any number of formation zones 8a-c may be treated or otherwise serviced using the completion system 1. For instance, while the completion system 1 is depicted as being arranged to treat multiple zones 8a-c, it is also contemplated to position a variation of the completion system 1 at a single zone, without departing from the scope of the disclosure.

[0021] As depicted in FIG. 1, portions of the wellbore 6 may be lined with casing 10 and cemented therein, as known in the art. The remaining portions of the wellbore 6, including the portions encompassing the formation zones 8a-c, may form part of an open hole section 12 of the wellbore 6 and the completion string 2 may be configured to be generally arranged therein during operation. In other embodiments, however, the casing 10 may extend further into the wellbore 6 and otherwise encompass one or more of the formation zones 8a-c, without departing from the scope of the disclosure.

[0022] Several perforations 14 may be initiated at or in each formation zone 8a-c and configured to provide fluid communication between each respective formation zone 8a-c and the annulus 24a-c (shown as a first annulus 24a, a second annulus 24b, and a third annulus 24c) formed between the completion string 2 and walls of the open hole section 12. Particularly, a first annulus 24a may be generally defined between the first formation zone 8a and the completion string 2. Second and third annuli 24b and 24c may similarly be defined between the second and third formation zones 8b and 8c, respectively, and the completion string 2. In embodiments where the casing 10 extends across the formation zones 8a-c, the casing 10 may also be perforated to allow fluid flow into each annulus 24a-c.

[0023] The completion string 2 may include a top packer 16 including slips (not shown) configured to support the completion string 2 within the casing 10 when properly deployed. In some embodiments, the top packer 16 may be a VERSA-TRIEVE® hangar packer commercially available from Halliburton Energy Services of Houston, Texas, USA. Disposed below the top packer 16 may be one or more isolation packers 18 (three shown as packers 18a, 18b, and 18c) and a sump packer 28, which cooperatively define individual production intervals corresponding to the various formation zones 8a-c between adjacent packers 18a-c and 28.

[0024] One or more shifting sleeves 20 (three shown in phantom as shifting sleeves 20a, 20b, and 20c) and one or more sand screens 22 (three shown as sand screens 22a, 22b, and 22c) may be arranged in each production interval. Each shifting sleeve 20a-c may be movably arranged within the completion string 2 and, as will be discussed below, may be configured to axially translate between open and closed positions. First, second, and third circulation ports 26a, 26b, and 26c may be defined in the completion string 2 at the first, second, and third shifting sleeves 20a-c, respectively. When the shifting sleeves 20a-c are moved into their respective open positions, the circulation ports 26a-c are exposed and may thereby provide fluid communication between the interior of the completion string 2 and the corresponding annuli 24a-c.

[0025] A service tool (not visible in FIG. 1), also known as a gravel pack service tool or a completion service tool, may be extended from a surface location and positioned within the completion string 2 to regulate the gravel packing and hydraulic fracturing processes of each zone 8a-c. As will be discussed below, the service tool may include one or more shifting tools (not shown) used to open and close the shifting sleeves 20a-c. The service tool may also include a valve (not shown) that helps facilitate the introduction of a gravel pack within each annulus 24a-c and also facilitate the hydraulic fracturing process through the corresponding circulation ports 26a-c.

[0026] In some embodiments, the completion system 1 may further include one or more control lines 30 (one shown) extending externally along the completion string 2 and within each annulus 24a-c. The isolation packers 18a-c may include or otherwise be configured for control line bypass, which allows the control line 30 to pass therethrough external to the completion string 2. The control line 30 may be representative of or otherwise include one or more

electrical lines, one or more fiber optic lines, and/or one or more hydraulic lines used to actuate various downhole tools or otherwise report various fluid properties and well environment parameters within each annulus 24a-c during both the gravel packing and fracking operations.

5 **[0027]** Even though FIG. 1 depicts a vertical well, it will be appreciated by those skilled in the art that the principles of the present disclosure are equally well-suited for use in deviated wells, inclined wells, or horizontal wells. Additionally, even though FIG. 1 has been described with reference to a gravel packing operation, it should be noted that the principles of the present disclosure
10 are equally well-suited for use in a variety of treatment operations where it is desirable to selectively move the shifting sleeves 20a-c between open and closed positions.

[0028] FIGS. 2A and 2B illustrate, respectively, a perspective view and a plan view of an exemplary shifting tool 100 with shifting keys 190a and 190b
15 in a retracted position, according to one or more embodiments. According to one or more embodiments, as illustrated in FIGS. 2A and 2B, the shifting tool 100 may include a main housing 110 from which one or both of the shifting keys 190a,b can be radially advanced and/or retracted by operation of a motor 120. Any number of shifting keys may be provided in any
20 orientation. For example, one shifting key 190 or more than one shifting key 190 can be provided. A plurality of shifting keys 190 can have the same axial alignment or different axial alignments. A plurality of shifting keys 190 can be circumferentially distributed about a central axis in a symmetrical or asymmetrical distribution.

25 **[0029]** FIGS. 2C and 2D illustrate, respectively, exposed perspective and plan views of the shifting tool 100, according to one or more embodiments. According to one or more embodiments, as illustrated in FIGS. 2C and 2D, an upper detent housing 146 is also advanceable along the shifting rod 180. The upper detent housing 146 is connected to the lower detent housing 170 by at
30 least one detent arm 148 that is fixed to the upper detent housing 146 and axially moveable through the lower detent housing 170 between an advanced position and a retracted position. A detent spring 162 is biased to urge the lower detent housing 170 away from the upper detent housing 146. As used herein, the detent spring 162 can be a compression spring or any another
35 mechanism that provides a force in response to compression thereof. Under

certain conditions, advancement of the upper detent housing 146 transmits a force to the lower detent housing 170 or a force to the detent spring 162, as discussed further herein.

[0030] According to one or more embodiments, as illustrated in FIGS. 2C and 2D, a nut 142 can be connected to the upper detent housing 146 by one or more extension arms 144. The nut 142, the extension arms 144, and the upper detent housing 146 can form an upper assembly 140 that moves in unison. The nut 142 can move along an upper rod 134 (FIG. 2D). The upper rod 134 can be fixed relative to the main housing 110, such that the upper assembly 140 can move relative to the main housing 110 by traveling along the upper rod 134.

[0031] FIG. 3A illustrates a cross-sectional side view of the exemplary shifting tool 100 in a retracted configuration, according to one or more embodiments. As illustrated in FIG. 3A, the main housing 110 can provide an upper chamber 112 and a lower chamber 116. The upper chamber 112 can be separated from the lower chamber 116 by a partition wall 114. The nut 142 can be disposed within the upper chamber 112, and the upper detent housing 146 can be disposed within the lower chamber 116. The extension arms 144 can extend through the partition wall 114 through one or more apertures defined therethrough.

[0032] According to one or more embodiments, as illustrated in FIGS. 3A and 3B, the shifting 100 tool includes a lower detent housing 170 connected to shifting keys 190a,b via linkages 174a,b, respectively. The shifting rod 180 can be fixed relative to the main housing 110, such that the lower detent housing 170 can move relative to the main housing 110 by traveling along the shifting rod 180. As the lower detent housing 170 is advanced or retracted, an attached end of each of the linkages 174a,b is correspondingly advanced or retracted. An opposite end of each of the linkages 174a,b that is attached to the shifting rod 180 remains stationary relative to the shifting rod 180. As the ends of each of the linkages 174a,b move toward each other, at least a portion of each of the linkages 174a,b move radially outwardly. As the ends of each of the linkages 174a,b move away from each other, at least a portion of each of the linkages 174a,b move radially inwardly. Accordingly, advancement and retraction of the lower detent housing 170 along the shifting rod 180 may result

in the shifting keys 190a,b extending radially outwardly and inwardly, respectively.

[0033] According to one or more embodiments, as illustrated in FIG. 3A, a return spring 160 is biased to urge the upper detent housing 146 along the shifting rod 180 in a direction that allows retraction of the shifting keys 190a,b toward the shifting rod 180. As used herein, the return spring 160 can be a compression spring or any another mechanism that provides a force in response to compression thereof. The return spring 160 can be biased to apply a force against a nut 142 that is connected to the upper detent housing 146. The return spring 160 can also apply a force against a portion of the main housing 110, such as the partition wall 114. Accordingly, the return spring 160 can urge the upper assembly 140 and components thereof relative to the main housing 110.

[0034] The motor 120 may be configured to advance and retract the upper assembly 140 (including the upper detent housing 146) along the shifting rod 180. During operation, the motor 120 can generate a force via an output shaft 122, wherein the force advances or retracts the nut 142, which thereby transmits the force to the upper detent housing 146. The motor 120 can generate a rotary force that is translated to linear motion of the upper assembly 140 via a ball screw device 132. As the motor 120 rotates, the ball screw device 132 causes a corresponding linear motion of the upper assembly 140. According to one or more embodiments, a torque-limiting clutch 130 can be provided between the motor 120 and the upper assembly 140 to controllably limit the forces applied to the upper assembly 140. The torque-limiting clutch 130 can be actively controlled during operation or preprogrammed to limit torque above a given threshold. Linear motion of upper and/or lower detent housings 146, 170 can cause a radial extension of linkages 174a,b and corresponding radial extension of the shifting keys 190a,b. Alternatively, a linear motor can be used to extend and retract the upper assembly 140.

[0035] According to one or more embodiments, the shifting keys 190 may be configured to automatically radially retract upon termination of power to the motor 120. More particularly, when the motor 120 and/or the torque-limiting clutch 130 are no longer powered, either by failure thereof or by deactivation, the return spring 160 may operate to urge the upper assembly 140 to move within the main housing 110. The lower detent housing 170 is likewise urged, causing the linkages 174a,b and the shifting keys 190a,b to retract

radially inwardly. The shifting keys 190a,b can retract based upon an attachment to the linkages 174a,b or based upon a separate mechanism that biases the shifting keys 190a,b to a radially retracted position.

[0036] As illustrated in FIG. 3A, the shifting tool 100 can be advanced
5 within the wellbore 6 to a given shifting sleeve 20. FIG. 3B illustrates a cross-sectional side view of the shifting tool 100 in an actuated configuration partially contacting the shifting sleeve 20. As discussed above, the motor 120 can cause axial advancement of the upper assembly 140, including the upper and lower detent housings 146, 170, and thereby actuate the linkages 174a,b to cause
10 radial extension of the shifting keys 190a,b. As shown, the shifting keys 190a,b may extend into contact with the engagement elements 32 of the shifting sleeve 20 before the profile 192 of a shifting key 190 is properly aligned with a corresponding engagement element 32. For example, a recess and/or protrusion can be configured to engage a complementary profile of the
15 engagement element 32 when properly axially aligned there with. When improperly aligned, the shifting key 190 is not permitted to radially extend to the same extent as when it is properly aligned. As such, the misaligned components force the shifting keys 190a,b into a partially radially retracted position. This position also forces the linkages 174a,b and the lower detent
20 housing 170 to become or remain partially retracted.

[0037] According to one or more embodiments, the lower detent housing 170 can achieve and maintain a partially retracted position while the upper detent housing 146 is fully extended based on operation of the motor 120. As the motor 120 advances the upper assembly 140, the return spring 160 may
25 be compressed. The upper assembly 140 can be extended to a position corresponding to a desired extension of the shifting keys 190a,b. Such a position can be achieved, for example, when the return spring 160 is fully compressed. Upon full extension of the upper assembly 140, the torque limiting clutch 130 can allow a degree of slip to prevent further force transmission and to
30 prevent the motor 120 from stalling.

[0038] As shown in the enlarged view of FIG. 3B, the detent arms 148 extending from the upper detent housing 146 can provide a narrow section 149 that extends through an aperture 172 of the lower detent housing 170. The narrow section 149 can have a smaller cross-sectional diameter than axially
35 adjacent portions of the detent arm 148 and/or a detent end portion 150. For

example, the relatively larger cross-sectional dimensions of the detent arm 148 and the detent end portion 150 are too large to pass through the aperture 172 of the lower detent housing 170. Accordingly, the narrow section 149 slides within the aperture 172 to allow a degree of axial movement of the upper assembly 140, including the upper detent housing 146, relative to the lower detent housing 170. For any given position within the aperture 172, the narrow section 149 forms a gap 152 on one or both sides of the lower detent housing 170. In the configuration shown in FIG. 3B, the force applied by the motor 120 is transmitted to the upper detent housing 146. An opposing force is applied by contact between the shifting keys 190a,b and the engagement element 32 and transmitted to the lower detent housing 170. The opposing forces applied to the upper detent housing 146 and the lower detent housing 170 cause compression of the detent spring 162, which thereby stores energy as it is compressed.

[0039] FIG. 3C illustrates a cross-sectional side view of the shifting tool 100 in an actuated configuration engaged to the shifting sleeve 20, according to one or more embodiments. As shown in FIG. 3C, the shifting keys 190a,b can become properly aligned with the engagement elements 32 of the shifting sleeve 20 such that complementary profiles are matched. When properly aligned, each shifting key 190a,b is permitted to radially extend to a greater extent than while improperly aligned. The lower detent housing 170 can achieve and maintain a fully extended position. As the shifting keys 190a,b mate with the engagement elements 32, the detent spring 162 urges the lower detent housing 170 forward and the shifting keys 190a,b radially outwardly. The narrow section 149 slides within the aperture 172 to allow the energy stored in the detent spring 162 to be at least partially released. The gap 152 may form on an opposite side of the lower detent housing 170. Accordingly, the motor 120 can be operated to fully extend the upper assembly 140, including the upper detent housing 146, before the shifting keys 190a,b contact or fully engage the engagement element 32. In such a configuration, the shifting keys 190a,b automatically extend and engage without continuing adjustment of the upper assembly 140.

[0040] Upon engagement, the shifting keys 190a,b can maintain the position of the shifting tool 100 relative to the shifting sleeve 20. Accordingly, axial movement of the shifting tool 100 during engagement can cause corresponding axial movement of the shifting sleeve 20. As such, the shifting sleeve 20 can be moved within the wellbore 6. Axial movement of the shifting

sleeve 20 can correspond to one or more of a variety of functions associated with a wellbore and operation thereof. For example, as discussed herein, actuation of the shifting sleeve 20 can be employed with operation of a sand screen for formation of a gravel pack in a gravel packing operation. By further example, shifting sleeves can be actuated to shut off flow from one or more reservoir zones or to regulate pressure between zones. Furthermore, actuation of a shifting sleeve as disclosed herein can be applied to any selective engagement and controlled motion of wellbore components and completion systems, as executed by a downhole tool.

10 **[0041]** FIG. 3D illustrates a cross-sectional side view of the shifting tool 100 in a retracted configuration, according to one or more embodiments. As shown in FIG. 3D, the upper assembly 140 can be retracted by operation or deactivation of the motor 120. For example, the motor 120 can be operated to retract the upper assembly 140. Alternatively or in combination, deactivation of
15 the motor 120 can allow the return spring 160 to release stored energy and cause the knot 142 to move away from the wall partition 114. In the absence of sufficient counterforce from the motor 120, the return spring 160 causes the upper assembly 142 return to a retracted configuration. Accordingly, the lower detent housing 170 also retracts, allowing the linkages 174a,b and the shifting
20 keys 190a,b to radially retract. Such actions can be achieved based on passive mechanisms, such as the return spring 160 and/or any other biasing mechanisms to cause retraction of the upper assembly 140, the lower detent housing 170, the linkages 174a,b, and/or the shifting keys 190a,b. As such, a loss of power to the motor 120 can automatically allow the shifting keys 190a,b
25 to retract without active operation of the system.

[0042] Referring now to FIGS. 4A and 4B, illustrated is another exemplary shifting tool 200, according to one or more embodiments. The shifting tool 200 may be substantially similar to the shifting tool 100 described above with reference to FIGS. 2A-3D, and therefore may be best understood
30 with reference to FIGS. 2A-3D, where like numerals and references refer to like components that will not be described again. As illustrated, the shifting tool 200 may include shifting keys 190a,b and a main housing 110 from which one or more shifting keys 190a,b can be radially advanced and/or retracted by operation of a motor 120. As with prior embodiments, any number of shifting
35 keys may be provided in any orientation.

[0043] FIG. 4A illustrates a cross-sectional side view of the shifting tool 200 in a retracted configuration, according to one or more embodiments. As illustrated, the shifting 200 tool includes the lower detent housing 170 that may be connected to one or more wedge cams 274. Advancement of the lower
5 detent housing 170 along the shifting rod 180 can axially advance the wedge cams 274. Each wedge cam 274 protrudes radially outwardly to provide a variable outer cross-sectional dimension along an axial length. For example, the wedge cams 274 can provide a surface that transitions from a minimum outer cross-sectional dimension of an end portion 272 to a maximum outer cross-
10 sectional dimension of the one or more wedge cams 274. As shown in FIG. 4A, the leading surface of the wedge cams 274 can form a ramp. Alternatively or in combination, the leading surface of the wedge cams 274 can be tapered, conical, frustoconical, curved, linear, or combinations thereof.

[0044] According to one or more embodiments, each wedge cam 274
15 can interact with an engagement member 276 positioned on a corresponding one of the shifting keys 190a,b. Each engagement member 276 can extend radially inwardly from the associated shifting key 190a,b to provide a variable inner cross-sectional dimension along an axial length of the shifting key 190a,b. As shown in FIG. 4A, the engagement member 276 can form an arc.
20 Alternatively or in combination, the engagement member 276 can be ramped, tapered, conical, frustoconical, curved, linear, or combinations thereof. At least a portion of the engagement members 276 can form a shape that is configured to interact with the wedge cams 274, such that axial motion of the wedge cams 274 facilitates radial extension of the shifting keys 190a,b. The engagement
25 member 276 can be a rigid or flexible material.

[0045] When the end portion 272 is axially aligned with the engagement members 276, the shifting keys 190a,b are permitted to remain in a radially retracted position. FIG. 4B illustrates a cross-sectional side view of the
30 shifting tool 200 in an actuated configuration, according to one or more embodiments. As shown, when the lower detent housing 170 is advanced such that the wedge cams 274 are axially aligned with the engagement members 276, the shifting keys 190a,b are radially extended.

[0046] As with prior embodiments, the upper detent housing 146 of the shifting tool 200 can be connected to the lower detent housing 170 by at least
35 one detent arm 148 that is fixed to the upper detent housing 146 and axially

moveable through the lower detent housing 170 between an advanced position and a retracted position. A detent spring 162 is biased to urge the lower detent housing 170 and the wedge cams 274 away from the upper detent housing 146. As with prior embodiments, when the shifting keys 190a,b become properly aligned with the engagement elements 32, the detent spring 162 urges the lower detent housing 170 and the wedge cams 274 axially forward and the shifting keys 190a,b radially outwardly. Alternatively or in combination, when the shifting keys 190a,b become properly aligned with the engagement elements 32, the engagement members 276 can urge the shifting keys 190a,b radially outwardly.

[0047] As with prior embodiments, the shifting keys 190 of the shifting tool 200 can be configured to automatically radially retract upon termination of power to the motor 120. When the motor 120 and/or the torque-limiting clutch 130 is no longer powered, either by failure thereof or by deactivation, the return spring 160 urges the upper assembly 140 to move within the main housing 110. The lower detent housing 170 is likewise urged, causing the wedge cams 274 to axially retract and the shifting keys 190a,b to retract radially inwardly.

[0048] Embodiments disclosed herein include:

[0049] A. A shifting tool that includes at least one shifting key, a lower detent housing operatively connected to the at least one shifting key such that advancement of the lower detent housing along a shifting rod advances the at least one shifting key radially away from the shifting rod, an upper detent housing slidably coupled to the lower detent housing, a detent spring biased to urge the lower detent housing away from the upper detent housing, and a return spring biased to urge the upper detent housing along the shifting rod in a direction that allows retraction of the at least one shifting key toward the shifting rod.

[0050] B. A well system that includes a casing string extending from a surface location within a wellbore, a shifting sleeve within the casing string, and a shifting tool, comprising at least one shifting key configured to engage the shifting sleeve, a lower detent housing connected to the at least one shifting key such that advancement of the lower detent housing along a shifting rod advances the at least one shifting key radially away from the shifting rod, an upper detent housing slidably coupled to the lower detent housing, a detent spring biased to urge the lower detent housing away from the upper detent

housing, and a return spring biased to urge the upper detent housing along the shifting rod in a direction that allows retraction of the at least one shifting key toward the shifting rod.

[0051] C. A method that includes positioning a shifting key of a shifting tool in a vicinity of an engagement element of a shifting sleeve within a casing string, axially advancing an upper detent housing and a lower detent housing of the shifting tool with an advancing force and radially advancing at least a portion of the shifting key against the engagement element, axially moving the shifting sleeve within the casing string via an axial load from the shifting tool, and if the advancing force is removed, axially retracting the upper detent housing and the lower detent housing with a return spring and radially retracting the shifting key.

[0052] Each of embodiments A, B, and C may have one or more of the following additional elements in any combination: Element 1: further comprising a motor configured to advance and retract the upper detent housing along the shifting rod, a torque-limiting clutch, and a ball screw configured to translate rotary motion of the motor to axial motion of the upper detent housing. Element 2: wherein the lower detent housing is slidingly coupled to the upper detent housing by at least one detent arm that is fixed to the upper detent housing and axially moveable through the lower detent housing between an advanced position and a retracted position. Element 3: wherein the detent spring is biased to urge the detent arm to the retracted position. Element 4: wherein the at least one detent arm comprises an upper portion fixed to the upper detent housing, a narrow portion extending through the lower detent housing, and an end portion. Element 5: wherein a cross-sectional dimension of the narrow portion is smaller than a cross-sectional dimension of the upper portion and/or a cross-sectional dimension of the end portion. Element 6: wherein the lower detent housing transitions from the retracted position to the advanced position when a profile of the at least one shifting key is aligned with a complementary shape of an engagement element of a shifting sleeve. Element 7: wherein the lower detent housing is urged to the retracted position against a force of the detent spring when a profile of the at least one shifting key is misaligned with a complementary shape of an engagement element of a shifting sleeve. Element 8: wherein the at least one shifting key comprises a profile that is complementary with respect to an engagement element of a shifting sleeve.

[0053] Element 9: wherein the lower detent housing is slidably coupled to the upper detent housing by at least one detent arm that is fixed to the upper detent housing and axially moveable through the lower detent housing between an advanced position and a retracted position. Element 10: wherein the detent spring is biased to urge the detent arm to the retracted position. Element 11: wherein the at least one detent arm comprises an upper portion fixed to the upper detent housing, a narrow portion extending through the lower detent housing, and an end portion. Element 12: wherein a cross-sectional dimension of the narrow portion is smaller than a cross-sectional dimension of the upper portion and/or a cross-sectional dimension of the end portion. Element 13: wherein the lower detent housing transitions from the retracted position to the advanced position when a profile of the at least one shifting key is aligned with a complementary shape of an engagement element of a shifting sleeve. Element 14: wherein the lower detent housing is urged to the retracted position against a force of the detent spring when a profile of the at least one shifting key is misaligned with a complementary shape of an engagement element of a shifting sleeve.

[0054] Element 15: further comprising misaligning the shifting key with a complementary shape of the engagement elements, and retracting the lower detent housing the upper detent housing against a force of a detent spring, wherein the detent spring is biased to urge the lower detent housing away from the upper detent housing. Element 16: further comprising, if the shifting key is aligned with the complementary shape, allowing the lower detent housing to advance away from the upper detent housing. Element 17: wherein the lower detent housing is urged away from the upper detent housing by a detent spring between the lower detent housing and the upper detent housing.

[0055] By way of non-limiting example, exemplary combinations applicable to A, B, and C include: Element 2 with Element 3; Element 2 with Element 4; Element 2 with Element 5; Element 2 with Element 6; Element 2 with Element 7; Element 9 with Element 10; Element 9 with Element 11; Element 9 with Element 12; Element 9 with Element 13; and Element 9 with Element 14.

[0056] Therefore, the disclosed systems and methods are well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the

5 teachings of the present disclosure may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered, combined, or modified and all such variations are considered within the scope of the present disclosure. The systems and methods illustratively disclosed herein may suitably be practiced in the absence of any element that is not specifically disclosed herein and/or any optional element disclosed herein. While compositions and methods are described in terms of "comprising," "containing," or "including" various components or steps, the compositions and methods can also "consist essentially of" or "consist of" the various components and steps. All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the element that it introduces. If there is any conflict in the usages of a word or term in this specification and one or more patent or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

20 **[0057]** As used herein, the phrase "at least one of" preceding a series of items, with the terms "and" or "or" to separate any of the items, modifies the list as a whole, rather than each member of the list (i.e., each item). The phrase "at least one of" does not require selection of at least one item; rather, the phrase allows a meaning that includes at least one of any one of the items, and/or at least one of any combination of the items, and/or at least one of each of the items. By way of example, the phrases "at least one of A, B, and C" or "at least one of A, B, or C" each refer to only A, only B, or only C; any combination of A, B, and C; and/or at least one of each of A, B, and C.

[0058] The use of directional terms such as above, below, upper, lower, upward, downward, left, right, uphole, downhole and the like are used in relation to the illustrative embodiments as they are depicted in the figures, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure, the uphole direction being toward the surface of the well and the downhole direction being toward the toe of the well.

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CLAIMS

What is claimed is:

1. A shifting tool, comprising:
at least one shifting key;
a lower detent housing operatively connected to the at least one shifting key such that advancement of the lower detent housing along a shifting rod advances the at least one shifting key radially away from the shifting rod;
an upper detent housing slidably coupled to the lower detent housing;
a detent spring biased to urge the lower detent housing away from the upper detent housing; and
a return spring biased to urge the upper detent housing along the shifting rod in a direction that allows retraction of the at least one shifting key toward the shifting rod.
2. The shifting tool of claim 1, further comprising:
a motor configured to advance and retract the upper detent housing along the shifting rod;
a torque-limiting clutch; and
a ball screw configured to translate rotary motion of the motor to axial motion of the upper detent housing.
3. The shifting tool of claim 1, wherein the lower detent housing is slidably coupled to the upper detent housing by at least one detent arm that is fixed to the upper detent housing and axially moveable through the lower detent housing between an advanced position and a retracted position.
4. The shifting tool of claim 3, wherein the detent spring is biased to urge the detent arm to the retracted position.
5. The shifting tool of claim 3, wherein the at least one detent arm comprises an upper portion fixed to the upper detent housing, a narrow portion extending through the lower detent housing, and an end portion.
6. The shifting tool of claim 3, wherein a cross-sectional dimension of the narrow portion is smaller than a cross-sectional dimension of the upper portion and/or a cross-sectional dimension of the end portion.
7. The shifting tool of claim 3, wherein the lower detent housing transitions from the retracted position to the advanced position when a profile of

the at least one shifting key is aligned with a complementary shape of an engagement element of a shifting sleeve.

8. The shifting tool of claim 3, wherein the lower detent housing is urged to the retracted position against a force of the detent spring when a profile of the at least one shifting key is misaligned with a complementary shape of an engagement element of a shifting sleeve.

9. The shifting tool of claim 1, wherein the at least one shifting key comprises a profile that is complementary with respect to an engagement element of a shifting sleeve.

10. A well system, comprising:

a casing string extending from a surface location within a wellbore;

a shifting sleeve within the casing string; and

a shifting tool, comprising:

at least one shifting key configured to engage the shifting sleeve;

a lower detent housing connected to the at least one shifting key such that advancement of the lower detent housing along a shifting rod advances the at least one shifting key radially away from the shifting rod;

an upper detent housing slidably coupled to the lower detent housing;

a detent spring biased to urge the lower detent housing away from the upper detent housing; and

a return spring biased to urge the upper detent housing along the shifting rod in a direction that allows retraction of the at least one shifting key toward the shifting rod.

11. The shifting tool of claim 10, wherein the lower detent housing is slidably coupled to the upper detent housing by at least one detent arm that is fixed to the upper detent housing and axially moveable through the lower detent housing between an advanced position and a retracted position.

12. The shifting tool of claim 11, wherein the detent spring is biased to urge the detent arm to the retracted position.

13. The shifting tool of claim 11, wherein the at least one detent arm comprises an upper portion fixed to the upper detent housing, a narrow portion extending through the lower detent housing, and an end portion.

14. The shifting tool of claim 11, wherein a cross-sectional dimension of the narrow portion is smaller than a cross-sectional dimension of the upper portion and/or a cross-sectional dimension of the end portion.

15. The shifting tool of claim 11, wherein the lower detent housing transitions from the retracted position to the advanced position when a profile of the at least one shifting key is aligned with a complementary shape of an engagement element of a shifting sleeve.

16. The shifting tool of claim 11, wherein the lower detent housing is urged to the retracted position against a force of the detent spring when a profile of the at least one shifting key is misaligned with a complementary shape of an engagement element of a shifting sleeve.

17. A method, comprising:

positioning a shifting key of a shifting tool in a vicinity of an engagement element of a shifting sleeve within a casing string;

axially advancing an upper detent housing and a lower detent housing of the shifting tool with an advancing force and radially advancing at least a portion of the shifting key against the engagement element;

axially moving the shifting sleeve within the casing string via an axial load from the shifting tool; and

if the advancing force is removed, axially retracting the upper detent housing and the lower detent housing with a return spring and radially retracting the shifting key.

18. The method of claim 17, further comprising:

misaligning the shifting key with a complementary shape of the engagement elements; and

retracting the lower detent housing the upper detent housing against a force of a detent spring, wherein the detent spring is biased to urge the lower detent housing away from the upper detent housing.

19. The method of claim 17, further comprising, if the shifting key is aligned with the complementary shape, allowing the lower detent housing to advance away from the upper detent housing.

20. The method of claim 17, wherein the lower detent housing is urged away from the upper detent housing by a detent spring between the lower detent housing and the upper detent housing.

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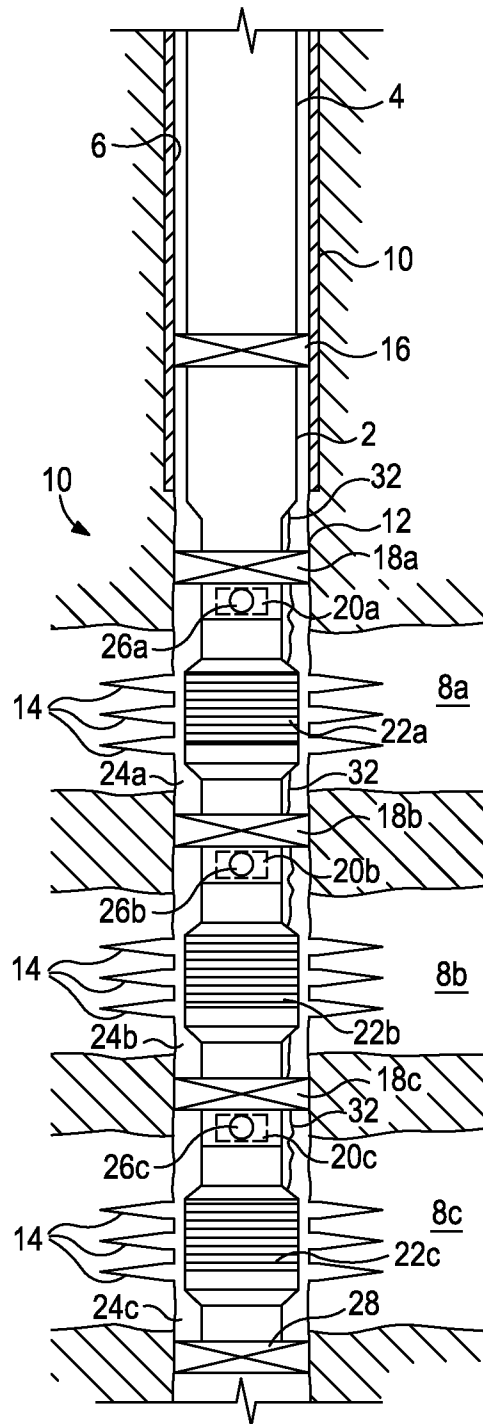


FIG. 1

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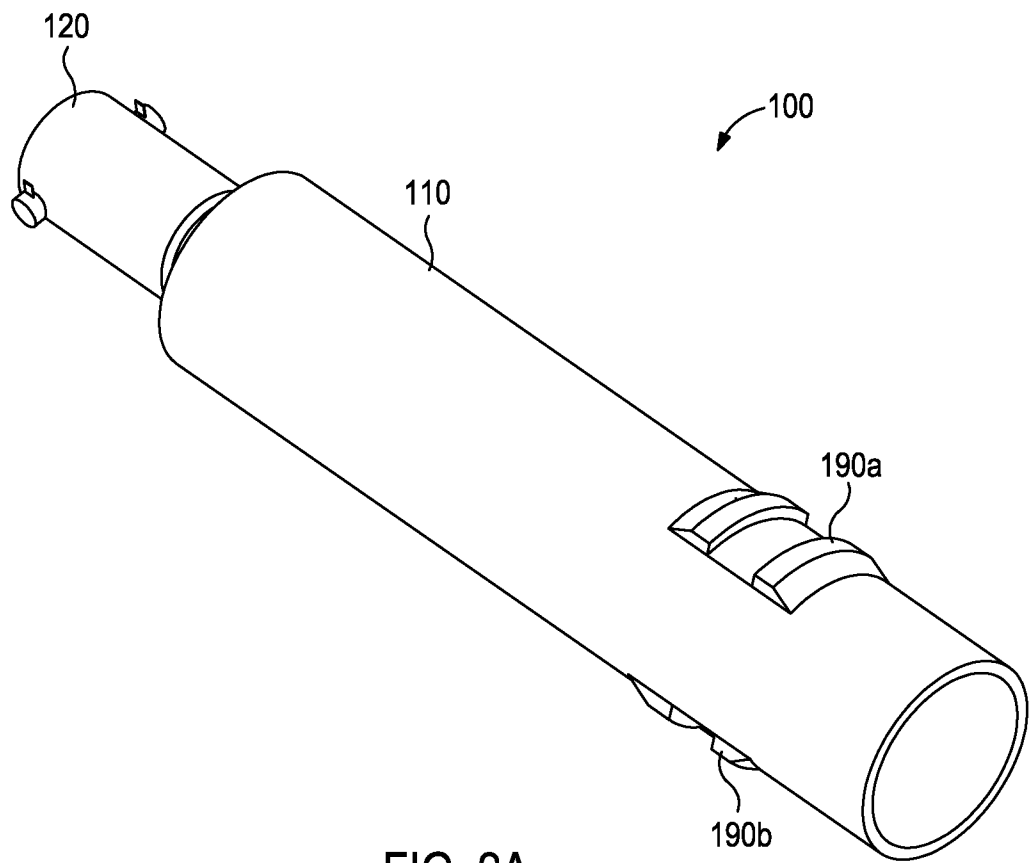


FIG. 2A

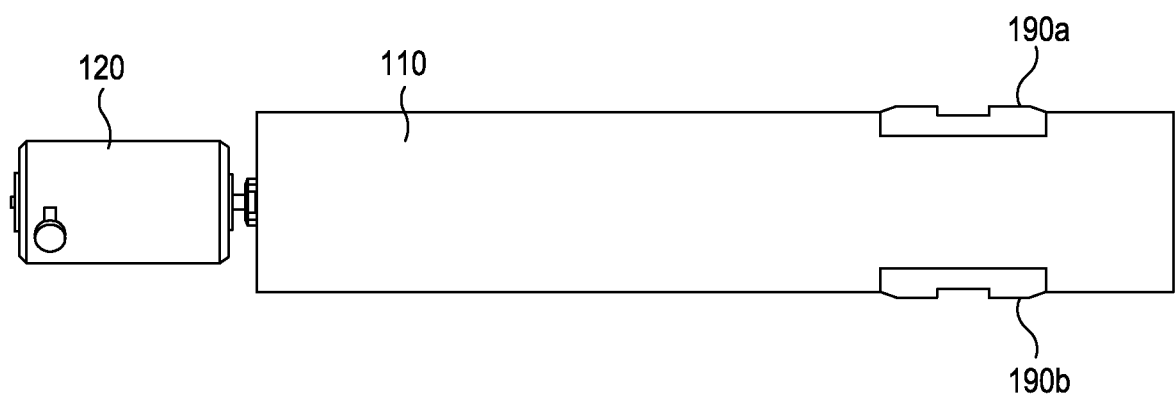


FIG. 2B

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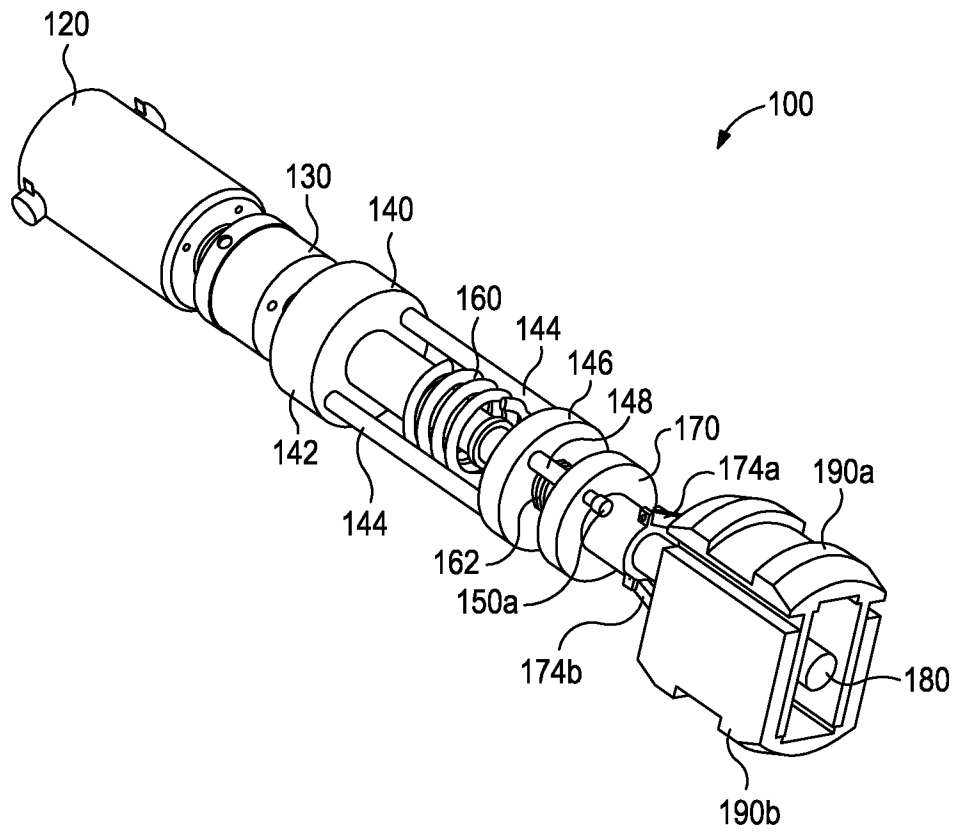


FIG. 2C

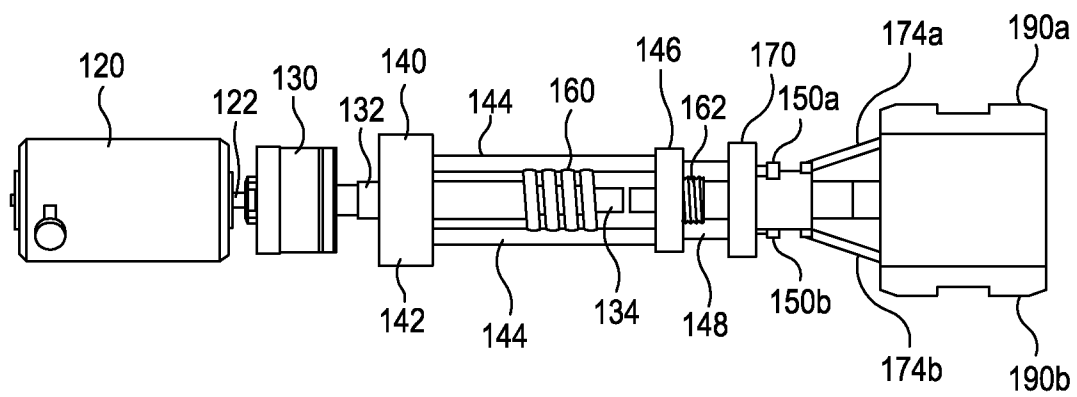


FIG. 2D

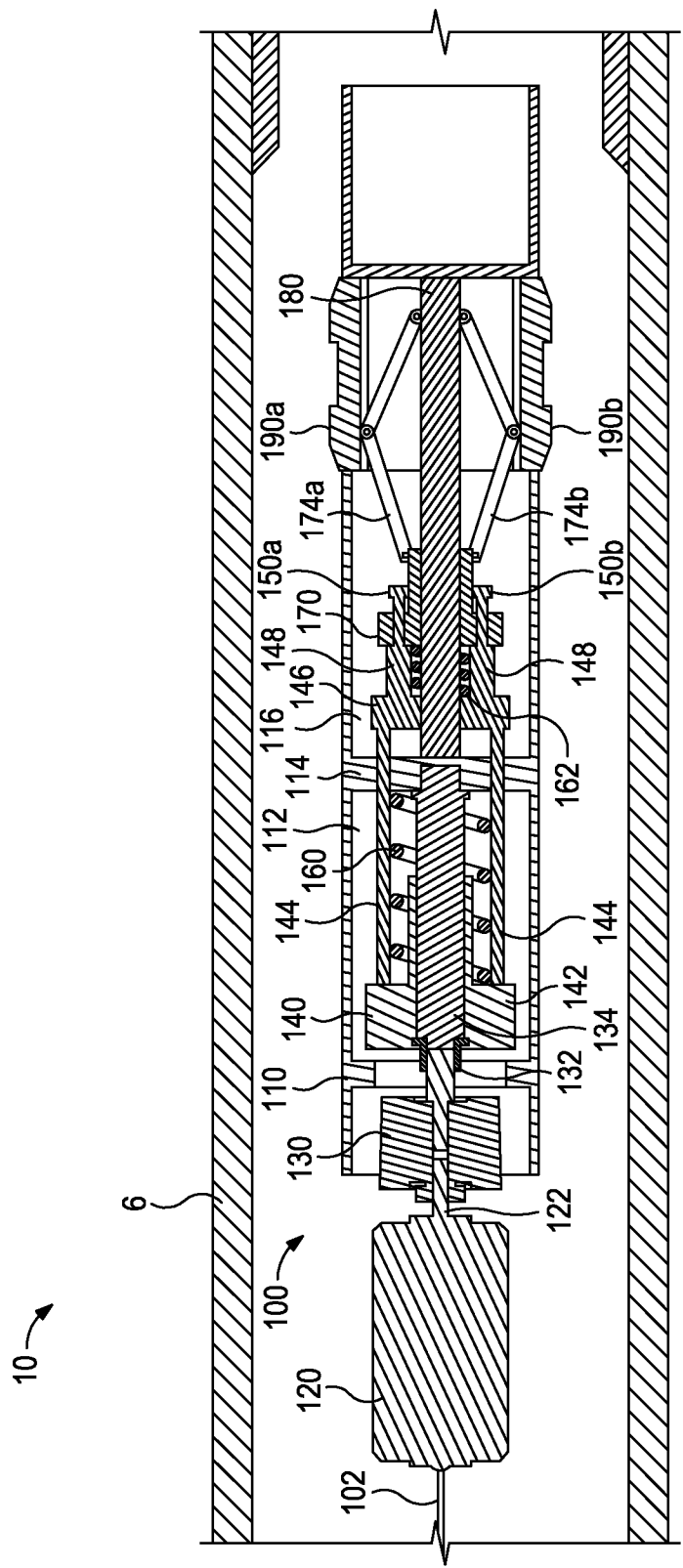


FIG. 3A

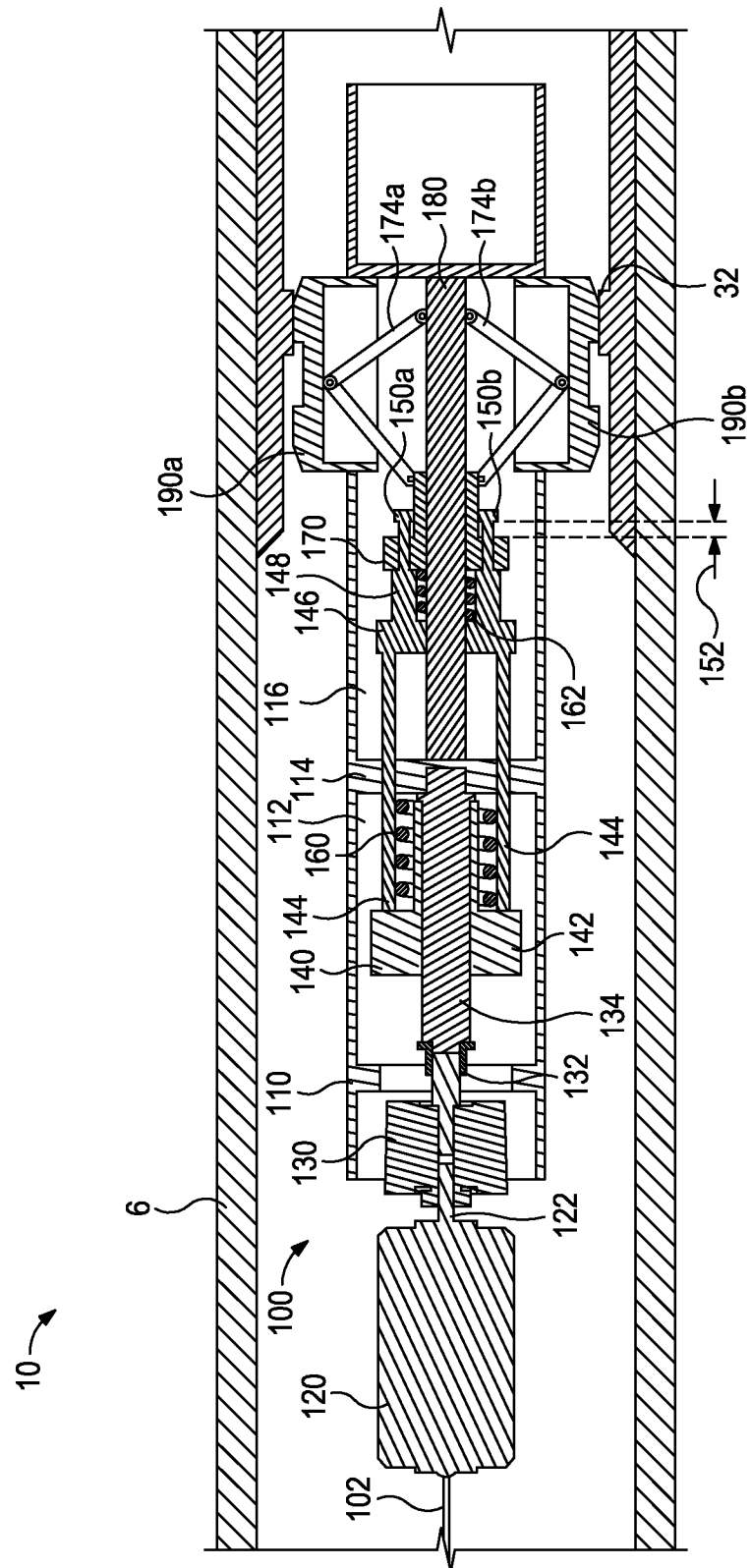


FIG. 3B

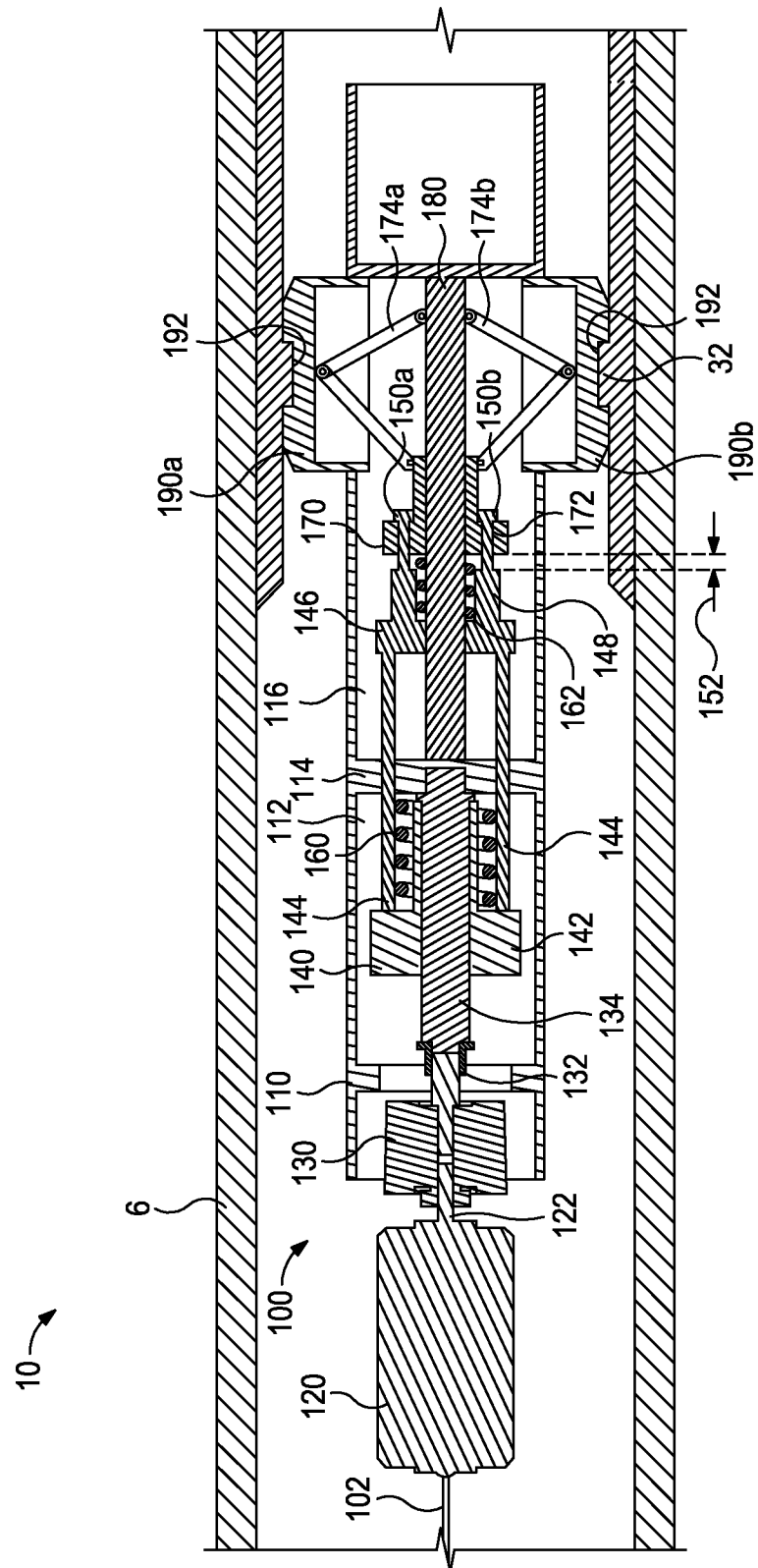


FIG. 3C

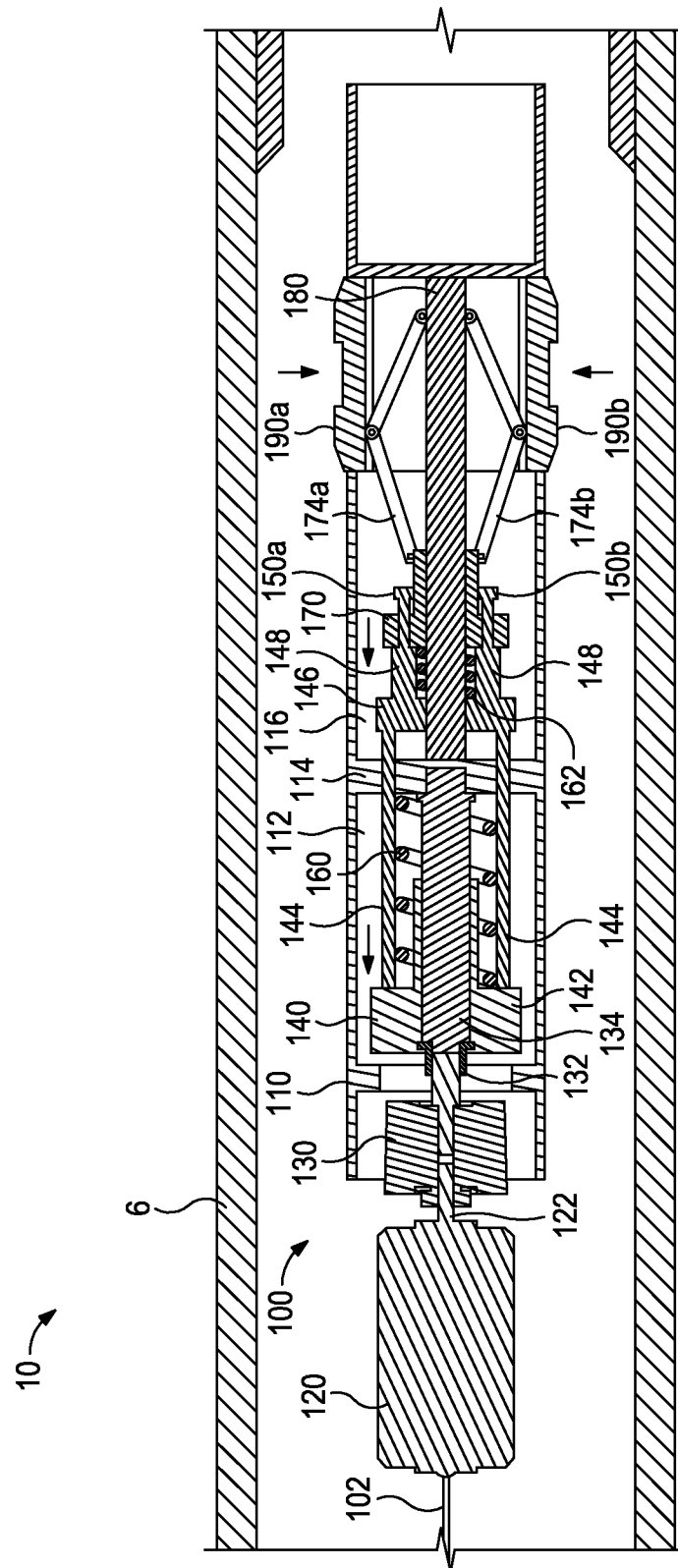


FIG. 3D

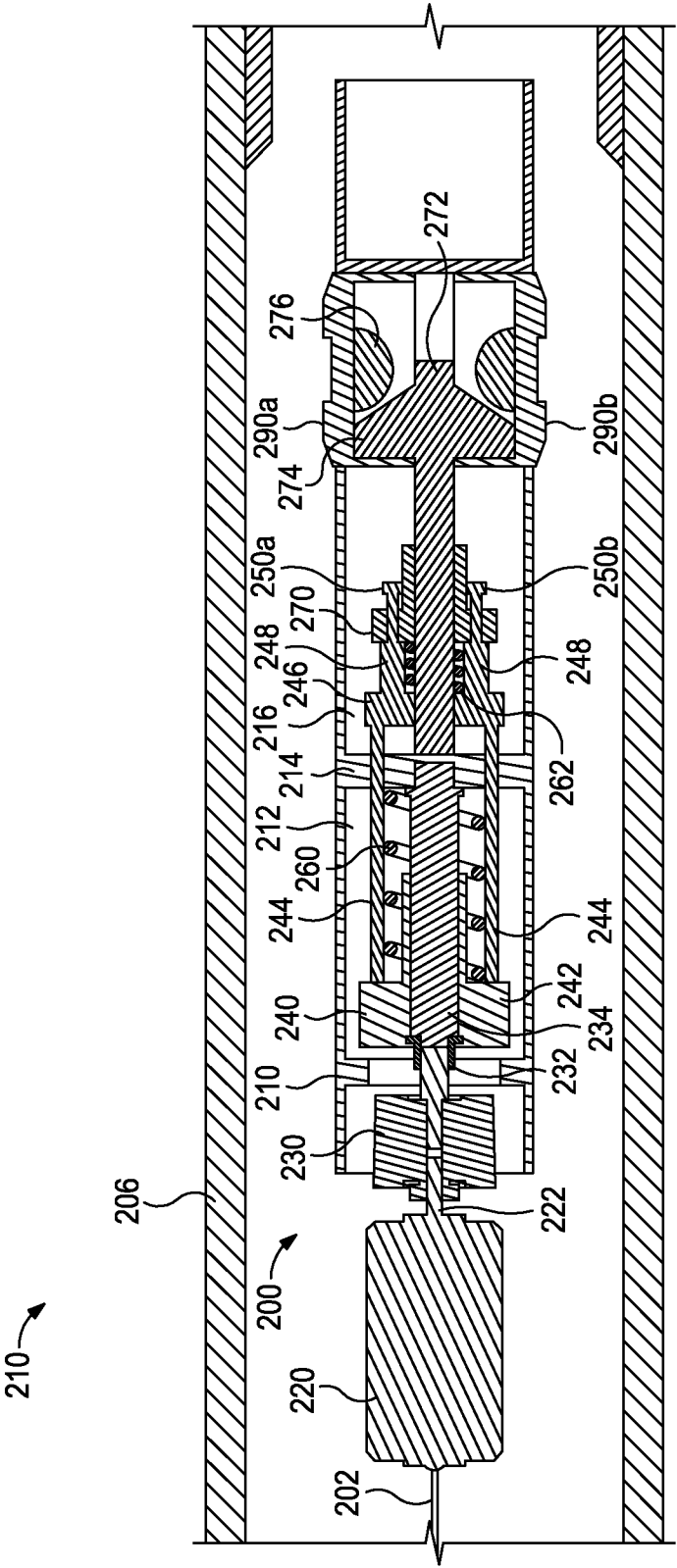


FIG. 4A

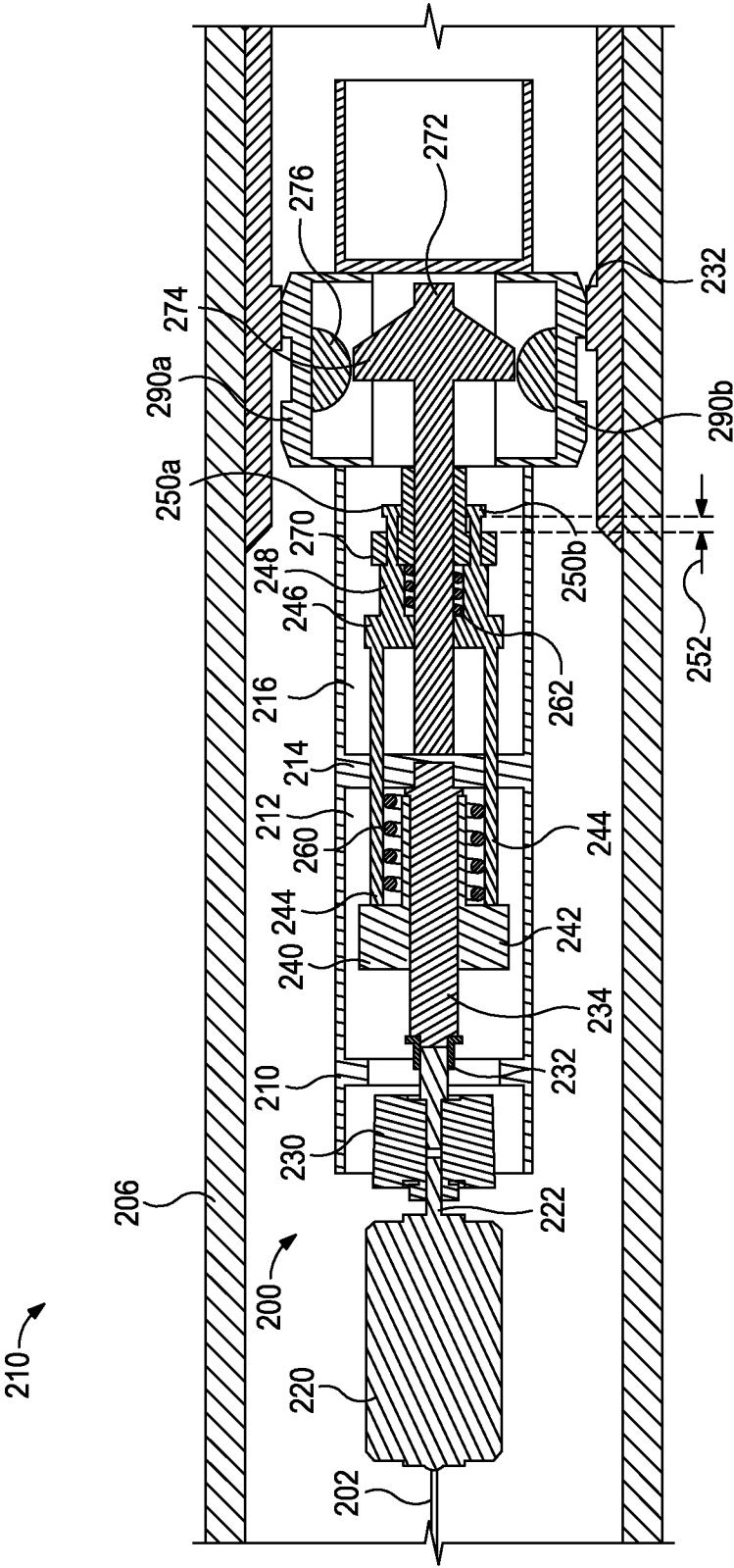


FIG. 4B

A. CLASSIFICATION OF SUBJECT MATTER**E21B 23/00(2006.01)i, E21B 34/06(2006.01)i, E21B 17/00(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 23/00; E21B 34/06; E21B 10/32; E21B 34/00; E21B 34/12; E21B 47/12; E21B 34/14; E21B 17/00

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: shifting tool, shifting key, detent spring, shape and sleeve

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0282475 A1 (DARNELL et al.) 11 November 2010 See paragraphs [0036]-[0039]; claim 18 and figures 1A-2B.	1-4, 10-12
Y		7-9, 15-16
A		5-6, 13-14, 17-20
Y	US 5549161 A (GOMEZ et al.) 27 August 1996 See column 4, line 47 - column 5, line 58 and figure 1A.	7-9, 15-16
A	US 2014-0338976 A1 (WEATHERFORD/LAMB, INC.) 20 November 2014 See paragraphs [0121]-[0133] and figures 10A-10F.	1-20
A	US 2012-0111579 A1 (RADFORD et al.) 10 May 2012 See paragraphs [0026]-[0031] and figures 3-4.	1-20
A	US 05305833 A (COLLINS, LEO G.) 26 April 1994 See column 4, line 67 - column 6, line 52 and figures 4-6C.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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

"&" document member of the same patent family

Date of the actual completion of the international search

17 November 2015 (17.11.2015)

Date of mailing of the international search report

18 November 2015 (18.11.2015)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 35208,
Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

RHEE, Jun Ho

Telephone No. +82-42-481-8288



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/020525

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