



(51) International Patent Classification:

E21B 43/25 (2006.01) *E21B 43/17* (2006.01)
E21B 43/26 (2006.01) *E21B 47/12* (2006.01)

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.

(21) International Application Number:

PCT/US2016/059641

(22) International Filing Date:

31 October 2016 (31.10.2016)

(25) Filing Language:

English

(26) Publication Language:

English

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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, DJ, 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, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA,

(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, ST, 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, 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))*

Published:

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

(54) Title: WIRELESS ACTIVATION OF WELLBORE COMPLETION ASSEMBLIES

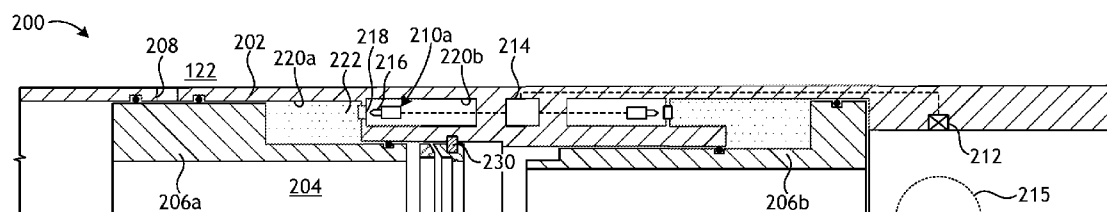


FIG. 2A

(57) Abstract: A completion section includes a base pipe defining a central flow passage, an injection port, and a production port. A fracturing assembly includes a frac sleeve positioned within the central flow passage adjacent the injection port, a sensor that detects a wireless signal, a first frac actuator actuatable in response to the wireless signal to move the frac sleeve and expose the injection port, and a second frac actuator actuatable based on the wireless signal to move the frac sleeve to occlude the injection port. A production assembly is axially offset from the fracturing assembly and includes a production sleeve positioned within the central flow passage adjacent the production port, a filtration device arranged about the base pipe, and a production actuator actuatable based on the wireless signal or an additional wireless signal to move the production sleeve to an open position where the production ports are exposed.



WIRELESS ACTIVATION OF WELLBORE COMPLETION ASSEMBLIES

BACKGROUND

[0001] Hydrocarbon-producing wells are often stimulated by hydraulic fracturing operations in order to enhance the production of hydrocarbons present in subterranean formations. During a typical fracturing operation, a servicing fluid (i.e., a fracturing fluid or a perforating fluid) is introduced into a wellbore that penetrates a subterranean formation and is injected into the subterranean formation at a hydraulic pressure sufficient to create or enhance a network of fractures therein. The resulting fractures serve to increase the conductivity potential for extracting hydrocarbons from the subterranean formation.

[0002] In some wellbores, it may be desirable to selectively generate multiple fracture networks along the wellbore at predetermined distances apart from each other, thereby creating multiple interval “pay zones” in the subterranean formation. Each pay zone may include a corresponding fracturing assembly used to initiate and carry out the hydraulic fracturing operation. Following the hydraulic fracturing operation, the fracturing assemblies are closed and corresponding production assemblies are initiated and operated to extract hydrocarbons from the various pay zones. Extracted hydrocarbons are then conveyed to the well surface for collection.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] 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 departing from the scope of this disclosure.

[0004] FIG. 1 is a well system that may employ the principles of the present disclosure.

[0005] FIGS. 2A-2E are cross-sectional side views of an example fracturing assembly.

[0006] FIGS. 3A and 3B are individual isometric views of an example embodiment of the magnetic projectile of FIG. 2A.

[0007] FIGS. 4A and 4B are cross-sectional side views of an example production assembly.

[0008] FIG. 5 is an isometric view of an example completion section that may form part of the completion assembly of FIG. 1, according to one or more embodiments.

[0009] FIG. 6A is a partial cross-sectional side view of the fracturing assembly of FIG. 5.

[0010] FIGS. 6B and 6C are enlarged cross-sectional side views of the first and second frac actuators of FIG. 6A, respectively, as indicated by the dashed boxes in FIG. 6A.

5 [0011] FIGS. 6D and 6E depict progressive views of the fracturing assembly of FIG. 6A during example operation.

[0012] FIG. 7A is a partial cross-sectional side view of the production assembly of FIG. 5.

10 [0013] FIG. 7B is an enlarged cross-sectional side view of the production actuator of FIG. 7A, as indicated by the dashed box in FIG. 7A.

[0014] FIG. 7C is a cross-sectional side view of the production assembly of FIG. 7A with the production sleeve moved to the open position.

[0015] FIGS. 8A and 8B are cross-sectional side views of an alternate embodiment of the fracturing assembly of FIGS. 6A-6E.

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DETAILED DESCRIPTION

[0016] The present disclosure is related to downhole completion assemblies in the oil and gas industry and, more particularly, to actuating fracturing and production assemblies using wireless communication to undertake hydraulic fracturing and production operations.

20 [0017] Embodiments disclosed herein describe the actuation (movement between open and closed positions) of fracture and production sleeves used in associated fracturing and production assemblies, respectively, through wireless means. One example, completion section for a downhole completion assembly includes a base pipe that defines a central flow passage, one or more injection ports, and one or more production ports. A fracturing
25 assembly is included in the completion section and includes a frac sleeve positioned within the central flow passage adjacent the injection ports, a sensor that detects a wireless signal, a first frac actuator actuatable in response to the wireless signal to move the frac sleeve and expose the injection ports, and a second frac actuator actuatable based on the wireless signal to move the frac sleeve to occlude the injection ports. A production assembly is also
30 included in the completion section and is axially offset from the fracturing assembly. The fracturing assembly includes a production sleeve positioned within the central flow passage adjacent the production ports, a filtration device arranged about the base pipe, and a production actuator actuatable based on the wireless signal or an additional wireless signal to move the production sleeve to an open position where the production ports are exposed.

[0018] FIG. 1 is a well system 100 that may employ the principles of the present disclosure, according to one or more embodiments of the disclosure. As depicted, the well system 100 includes a wellbore 102 that extends through various earth strata and has a substantially vertical section 104 that transitions into a substantially horizontal section 106. The upper portion of the vertical section 104 may be lined with a string of casing 108 cemented therein to support the wellbore 102, and the horizontal section 106 may extend through one or more hydrocarbon bearing subterranean formations 110. In at least one embodiment, as illustrated, the horizontal section 106 may comprise an open hole section of the wellbore 102. In other embodiments, however, the casing 108 may also extend into the horizontal section 106, without departing from the scope of the disclosure.

[0019] A work string 112 is extended into the wellbore 102 from a surface location, such as the Earth's surface, and may be used to convey ("run") a wellbore completion assembly 114 into the wellbore 102. As illustrated, the completion assembly 114 may be coupled to the end of the work string 112 and generally arranged within the horizontal section 106. In at least one embodiment, the completion assembly 114 divides the wellbore 102 into various production intervals or "pay zones" adjacent the subterranean formation 110. To accomplish this, as illustrated, the completion assembly 114 includes a plurality of wellbore packers 116 axially spaced from each other along the length of the completion assembly 114. Once set within the wellbore 102, each wellbore packer 116 provides a corresponding fluid seal between the completion assembly 114 and the inner wall of the wellbore 102, and thereby effectively defines discrete production intervals within the wellbore 102. Sections of the completion assembly 114 between axially adjacent wellbore packers 116 may be referred to herein as "completion sections," alternately referred to as production intervals.

[0020] It should be noted that even though FIG. 1 depicts multiple completion sections defined by the separating wellbore packers 116, the completion assembly 114 may provide any number of completion sections with a corresponding number of wellbore packers 116 arranged therein. In other embodiments, for example, the wellbore packers 116 may be entirely omitted from the completion assembly 114, and the system 100 may alternatively include only a single upper wellbore packer 117 that isolates the entire completion assembly 114 from upper portions of the wellbore 102.

[0021] In the illustrated embodiment, each completion section may include at least one fracturing assembly 118 and at least one production assembly 120. In other embodiments, however, such as in embodiments where the multiple wellbore packers 116 are replaced with the upper wellbore packer 117, the system 100 may alternatively include only

one fracturing assembly 118 and one or more production assemblies 120 used to service the entire completion assembly 114. The fracturing assembly(ies) 118 may be actuated or otherwise operated to inject a fluid into the annulus 122 defined between the completion assembly 114 and the wellbore 102. The fluid injected by the fracturing assemblies 118 may
5 comprise, for example, a fracturing fluid used to create a network of fractures in the surrounding formation 110. The fluid may also or alternatively comprise a gravel slurry that fills the annulus 122 following the creation of the fracture network. In yet other applications, the fluid injected by the fracturing assemblies 118 may comprise a stimulation fluid, a treatment fluid, an acidizing fluid, a conformance fluid, or any combination of the foregoing
10 fluids.

[0022] Upon closing the fracturing assembly(ies) 118, a corresponding production assembly 120 may subsequently be actuated or otherwise operated to draw in fluids from the formation 110 to be conveyed to the surface of the well for collection. Each production assembly 120 serves the primary function of filtering particulate matter out of the production
15 fluid stream originating from the formation 110 such that particulates and other fines are not produced to the surface. To accomplish this, the production assemblies 120 may include one or more filtration devices, such as well screens or slotted liners that allow fluids to flow therethrough but generally prevent the influx of particulate matter of a predetermined size.

[0023] While FIG. 1 depicts the completion assembly 114 as being arranged in a
20 generally horizontal section 106 of the wellbore 102, the completion assembly 114 is equally well suited for use in other directional configurations including vertical, deviated, slanted, or any combination thereof. The use of directional terms herein 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
25 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.

[0024] Actuation or operation of the fracturing assemblies 118 and the production assemblies 120 is conventionally undertaken by introducing a shifting tool downhole and
30 physically engaging and moving corresponding fracture and production sleeves between open and closed positions. According to embodiments of the present disclosure, however, actuating the corresponding fracture and production sleeves between open and closed positions may be accomplished through wireless means. In some embodiments, for instance, predetermined wireless signals may be conveyed and otherwise transmitted to one or both of

the fracturing and production assemblies 118, 120. Upon detection of the predetermined wireless signals, actuation of the fracturing and production assemblies 118, 120 may be triggered for operation. In other embodiments, however, one wireless signal may be provided and detected to operate a given fracturing assembly 118, and a corresponding production assembly 120 may be subsequently actuated based on a timer triggered by the wireless signal. The following discussion provides several examples as to how the fracturing and production assemblies 118, 120 may be wirelessly operated.

[0025] FIGS. 2A-2E are cross-sectional side views of an example fracturing assembly 200, according to one or more embodiments. The fracturing assembly 200 may be the same as or similar to the any of the fracturing assemblies 118 of FIG. 1 and, therefore, may be included in the completion assembly 114 (FIG. 1) and used to inject a fluid into the annulus 122 defined between the completion assembly 114 and the wellbore 102 (FIG. 1). FIGS. 2A-2E depict progressive views of the fracturing assembly 200 during example operation.

[0026] In FIG. 2A, the fracturing assembly 200 is depicted as including a base pipe 202 that defines a central flow passage 204. The base pipe 202 may form an integral part of the completion assembly 114 (FIG. 1), such as being coupled between opposing lengths of the completion assembly 114. As a result, the central flow passage 204 may be in fluid communication with the work string 112 (FIG. 1) such that fluids and objects (e.g., wellbore projectiles) conveyed into the wellbore 102 (FIG. 1) via the work string 112 will communicate with (flow into) the central flow passage 204.

[0027] The fracturing assembly 200 may further include a fracture sleeve 206a (alternately referred to as a “frac” sleeve) and a closure sleeve 206b, each being positioned for longitudinal movement within the central flow passage 204. One or more injection ports 208 (one shown) are defined in the wall of the base pipe 202 and are blocked (occluded) when the frac sleeve 206a is in a first or “closed” position, thereby preventing fluid communication between the annulus 122 and the central flow passage 204. As described below, however, the frac sleeve 206a is actuatable to move (i.e., displace) to a second or “open” position where the injection ports 208 are exposed.

[0028] To move the frac sleeve 206a to the open position, a first frac actuator 210a is triggered based on a wireless signal received or otherwise detected by a sensor 212. While the sensor 212 is shown located downhole from the frac sleeve 206a, the sensor 212 could alternatively be located uphole from the frac sleeve 206a, without departing from the scope of the disclosure. The sensor 212 may comprise a variety of types of downhole sensors configured to detect or otherwise receive a variety of wireless signals. Moreover, the

wireless signal may originate from a variety of locations, devices, or otherwise provided via a variety of means. In some applications, for example, the wireless signal may be transmitted from a well surface location or from an adjacent wellbore. In other applications, the wireless signal may be transmitted via a device or means located in or conveyed through the wellbore
5 102 (FIG. 1). In such embodiments, the device or means may comprise an untethered tool, but could alternately be attached to a conveyance, such as wireline or slickline.

[0029] In some embodiments, the sensor 212 may comprise a magnetic sensor configured to detect the presence of a magnetic field or property produced by a wellbore projectile conveyed through the central flow passage 204. In such embodiments, the sensor
10 212 may comprise, but is not limited to, a magneto-resistive sensor, a Hall-effect sensor, a conductive coil, or any combination thereof. In some embodiments, one or more permanent magnets can be combined with the sensor 212 to create a magnetic field that is disturbed by a wellbore projectile (or the like), and a detected change in said magnetic field can be an indication of the presence of the wellbore projectile.

[0030] In other embodiments, however, the sensor 212 may be configured to detect
15 other types of wireless signals such as, but not limited to, an electromagnetic signal, a pressure signal, a temperature signal, an acoustic signal (e.g., noise), a fluid flowrate signal, or any combination thereof. Consequently, the sensor 212 may alternatively comprise at least one of an antenna, a pressure sensor, a temperature sensor, an acoustic sensor, a vibration
20 sensor, a strain sensor, an accelerometer, a flow meter, or any combination thereof.

[0031] The sensor 212 is communicably connected to an electronics module 214 that includes electronic circuitry configured to determine whether the sensor 212 has detected a particular or predetermined wireless signal. The electronics module 214 may include a power supply, such as one or more batteries, a fuel cell, a downhole generator, or any other source
25 of electrical power used to power operation of one or more of the electronics module 214, the sensor 212, and the first frac actuator 210a.

[0032] In embodiments where the sensor 212 is a magnetic sensor, the electronic circuitry may be configured to determine whether the sensor 212 has detected a predetermined magnetic field, a pattern or combination of magnetic fields, or another
30 magnetic property of a magnetic projectile 215 (shown in dashed) introduced into the central flow passage 204. The magnetic projectile 215 may be pumped to or past the sensor 212 in order to transmit a magnetic signal to the first frac actuator 210a. The electronics module 214 may include a non-volatile memory having a database programmed with a predetermined

magnetic field(s) or other magnetic properties for comparison against magnetic fields/properties exhibited by the magnetic projectile 215 and detected by the sensor 212.

[0033] In the illustrated embodiment, the magnetic projectile 215 is depicted in the form of a sphere or ball, such as a frac ball known to those skilled in the art, but could alternatively comprise other shapes or types of wellbore projectiles, such as a dart or a plug. In other embodiments, the magnetic projectile 215 may comprise a fluid or a gel, such as a ferrofluid, a magnetorheological fluid, or another type of fluid that exhibits magnetic properties detectable by the sensor 212. In yet other embodiments, the magnetic projectile 215 might comprise a pill or slurry of magnetic particles pumped into the central flow passage 204 to be detected by the sensor 212. In even further embodiments, the magnetic projectile 215 may comprise a downhole tool, such as a perforating charge with a magnetic attachment added to the perforating charge.

[0034] In embodiments where the sensor 212 is a pressure sensor, predetermined pressure levels or sequences may be programmed into the memory of the electronics module 214 for comparison against an actual fluid pressure or a series (pattern) of pressure changes (fluctuations) detected in the central flow passage 204 by the sensor 212. Accordingly, to actuate the first frac actuator 210a, a well operator may selectively pressurize the central flow passage 204 to match one of the programmed pressure levels or sequences.

[0035] In embodiments where the sensor 212 is a temperature sensor, a predetermined temperature level or disparity (fluctuation) may be programmed into the memory of the electronics module 214 for comparison against the real-time temperature or temperature fluctuations detected in the central flow passage 204 by the sensor 212.

[0036] In embodiments where the sensor 212 is an acoustic sensor, predetermined acoustic signatures or acoustic sequences may be programmed into the memory of the electronics module 214 for comparison against noises or a series (pattern) of noise changes detected by the sensor 212. Such noises may be generated, for example, by axially translating and/or rotating a pipe string or other downhole tool within the wellbore. In other embodiments, however, the noises may comprise acoustic signals transmitted to the sensor 212 from a remote location, such as the well surface. In yet other embodiments, the noise may be generated by fluid movement.

[0037] If the electronics module 214 determines that the sensor 212 has affirmatively detected a predetermined or particular wireless signal, the electronic circuitry triggers actuation of the first frac actuator 210a to cause the frac sleeve 206a to move towards the open position to expose the injection ports 208.

[0038] In the illustrated example, the first frac actuator 210a includes a piercing member 216 operable to pierce a pressure barrier 218 that initially separates a first chamber 220a and a second chamber 220b each defined in the base pipe 202. The first frac actuator 210a can comprise any type of actuator (e.g., electrical, hydraulic, mechanical, explosive, chemical, a combination thereof, etc.) used to advance the piercing member 216 towards the pressure barrier 218 upon actuation. When the sensor 212 detects the predetermined wireless signal, the piercing member 216 pierces the pressure barrier 218, and a support fluid 222 (e.g., oil) flows from the first chamber 220a to the second chamber 220b, which generates a pressure differential across the frac sleeve 206a. The generated pressure differential urges the frac sleeve 206a to move (displace) toward the open position (i.e., to the right in FIG. 2A).

[0039] In some embodiments, the pressure differential generated by piercing the pressure barrier 218 may be sufficient to fully displace the frac sleeve 206a to its open position. In other embodiments, however, it may be required to pressurize the central flow passage 204 to move the frac sleeve 206a fully to its open position, as described below.

[0040] In FIG. 2B, the first frac actuator 210a is shown actuated as the piercing member 216 has pierced the pressure barrier 218 such that an amount of the support fluid 222 in the first chamber 220a is able to escape into the second chamber 220b. The support fluid 222 entering the second chamber 220b generates a pressure differential across the frac sleeve 206a that urges the frac sleeve 206a to displace downward (i.e., to the right in FIG. 2B) until engaging a baffle assembly 224 positioned in the central flow passage 204. As illustrated, the baffle assembly 224 includes a retractable baffle 226 and a baffle receiving sleeve 228 secured to the base pipe 202 with one or more shear members 230. As the frac sleeve 206a moves toward the open position it engages the retractable baffle 226 and forces the retractable baffle 226 against the baffle receiving sleeve 228. Opposing angled surfaces on the retractable baffle 226 and the baffle receiving sleeve 228 allow the retractable baffle 226 to slidingly engage and ride up onto the baffle receiving sleeve 228, and doing so radially contracts the retractable baffle 226 within the central flow passage 204 to a sealing position (i.e., a smaller inner diameter).

[0041] In this example, the retractable baffle 226 is in the form of an expandable ring that is contracted radially inward to its sealing position by the downward displacement of the frac sleeve 206a. In other examples, however, the retractable baffle 226 may comprise another type of radially contractible device or mechanism, without departing from the scope of the disclosure. Moreover, in this example further axial displacement of the frac sleeve

206a is prevented by the baffle receiving sleeve 228, which is secured to the base pipe 202 at the shear member 230.

[0042] In FIG. 2C, with the retractable baffle 226 in the sealing position, the central flow passage 204 may be sealed and otherwise isolated with an isolation device 232 used to isolate the fracturing assembly 200 from downhole portions. In the illustrated embodiment, the isolation device 232 is in the form of a wellbore projectile that may be conveyed downhole to help fully move the frac sleeve 206a to the open position. More specifically, the isolation device 232 is conveyed to the fracturing assembly 200 and into the central flow passage 204 to be received by the retractable baffle 226. While depicted in FIG. 2C as a ball-type wellbore projectile, the isolation device 232 may alternatively comprise a dart, a wiper, a plug, or any other type of known wellbore projectile. The isolation device 232 may be conveyed to the fracturing assembly 200 by any known technique, such as by being dropped through the work string 112 (FIG. 1), pumped through the central flow passage 204, self-propelled, conveyed by wireline, slickline, coiled tubing, etc.

[0043] In embodiments where the differential pressure acting on the frac sleeve 206a is not sufficient to overcome the shear limit of the shear member 230, the isolation device 232 may be used to seal the central flow passage 204 such that hydraulic pressure may be applied against the isolation device 232 to free the baffle receiving sleeve 228. The isolation device 232 may be sized to locate and land on the retractable baffle 226 in its sealing position and thereby create a sealed interface. Once the isolation device 232 lands on the retractable baffle 226, the fluid pressure in the central flow passage 204 may be increased to surpass the shear limit of the shear member 230 and thereby free the baffle receiving sleeve 228. With the shear member 230 sheared, the remaining differential pressure across the frac sleeve 206a generated between the first and second chambers 220a,b may urge the frac sleeve 206a to displace the baffle receiving sleeve 228 and move to the open position. Otherwise, hydraulic pressure on the isolation device 232 may help urge the frac sleeve 206a to the fully open position.

[0044] In FIG. 2D, the frac sleeve 206a is shown moved fully to the open position and the isolation device 232 continues to provide a sealed interface against the retractable baffle 226. A fluid 234 may then be flowed to the fracturing assembly 200 and into the central flow passage 204 at an elevated pressure to be injected into the annulus 122 via the exposed injection ports 208. The fluid 234 may comprise, for example, a fracturing fluid used to create a network of fractures in the surrounding formation 110 (FIG. 1) during a

hydraulic fracturing operation. Alternatively, or in addition thereto, the fluid 234 may comprise a gravel slurry used to fill the annulus 122 during a gravel packing operation.

[0045] After hydraulic fracturing operations have finished, it may be desired to move the frac sleeve 206a back to the closed position in preparation for production operations or alternatively in preparation for hydraulic fracturing of another zone within the wellbore. To accomplish this, a second frac actuator 210b included in the fracturing assembly 200 may be actuated or otherwise operated to move (displace) the closure sleeve 206b and thereby move the frac sleeve 206a back to the closed position. Similar to the first frac actuator 210a, in the illustrated example, the second frac actuator 210b includes a piercing member 236 configured to pierce a pressure barrier 238 that initially separates a third chamber 210c and a fourth chamber 210d each defined in the base pipe 202.

[0046] In some embodiments, actuation of the second frac actuator 210b to move the closure sleeve 206b may be time delayed. More specifically, the electronic circuitry of the electronics module 214 may include a timer that may be triggered (started) upon detection of the predetermined wireless signal used to actuate the first frac actuator 210a. In other applications, the timer may be triggered upon detection of a flow rate change through the central flow passage 204, a temperature change from the flow, etc. The timer may be programmed with a predetermined time period for actuating the second frac actuator 206b and, upon expiration of the predetermined time period, the electronics module 214 may actuate (operate) the second frac actuator 210b. The predetermined time period may be programmed to provide sufficient time to accomplish the hydraulic fracturing operations. For example, the predetermined time period may be about 6 hours, about 12 hours, about 24 hours, about 48 hours, more than 48 hours, or any time range falling therebetween. When the predetermined time period expires, the piercing member 236 is actuated to pierce the pressure barrier 238, and a support fluid 242 (e.g., oil) flows from the third chamber 210c to the fourth chamber 210d, which generates a pressure differential across the closure sleeve 206b. The generated pressure differential urges the closure sleeve 206b to move (displace) uphole (i.e., to the left in FIG. 2D) and toward the frac sleeve 206a and thereby move the frac sleeve 206a back to the closed position.

[0047] In other embodiments, however, a second or additional wireless signal may be detected by the sensor 212 to actuate the second frac actuator 210b. In such embodiments, the sensor 212 may be positioned uphole from the frac and closure sleeves 206a,b and otherwise able to detect signals uphole from the isolation device 232. The sensor 212,

however, need not be positioned uphole from the frac and closure sleeves 206a,b to detect the additional wireless signal.

[0048] In FIG. 2E, the frac sleeve 206a is shown moved back to the closed position by movement of the closure sleeve 206b, which is caused by the piercing member 236 penetrating the pressure barrier 238 to allow the support fluid 242 to flow to the fourth chamber 210d. As it moves in the uphole direction, the closure sleeve 206b axially engages the baffle receiving sleeve 228, which places an uphole axial load on the frac sleeve 206a toward the closed position. In some embodiments, an axial extension 240 of the closure sleeve 206b may engage the retractable baffle 226 and allow the retractable baffle 226 to radially expand once more to interpose the frac sleeve 206a and the baffle receiving sleeve 228. In such embodiments, the isolation device 232 (FIG. 2D) may be released to flow downhole as the retractable baffle 226 radially expands, and thereby clearing the central flow passage 204 for subsequent fluid flow through the fracturing assembly 200.

[0049] In other embodiments, the retractable baffle 226 may not be radially expanded as the closure sleeve 206b engages the retractable baffle 226 and moves the frac sleeve 206a back to closed position. In such embodiments, the isolation device 232 may alternatively be made of a degradable material that allows the isolation device 232 to dissolve over time and thereby clear the central flow passage 204 for subsequent fluid flow through the fracturing assembly 200. Suitable degradable materials for the isolation device 232 include, but are not limited to, a galvanically-corrodible metal (e.g., silver and silver alloys, nickel and nickel alloys, nickel-copper alloys, nickel-chromium alloys, copper and copper alloys, chromium and chromium alloys, tin and tin alloys, aluminum and aluminum alloys, iron and iron alloys, zinc and zinc alloys, magnesium and magnesium alloys, and beryllium and beryllium alloys), micro-galvanic metals or materials (e.g., nano-structured matrix galvanic materials, such as a magnesium alloy with iron-coated inclusions), and a degradable polymer (e.g., polyglycolic acid, polylactic acid, and thiol-based plastics).

[0050] FIGS. 3A and 3B are individual isometric views of an example embodiment of the magnetic projectile 215 of FIG. 2A. In the illustrated embodiment, the magnetic projectile 215 is in the general shape of a sphere 302, such as a frac ball known to those skilled in the art. The sphere 302 may include one or more magnets (not shown in FIGS. 3A and 3B) retained in a plurality of recesses 304 defined in the outer surface of the sphere 302. In other embodiments, however, the magnet(s) of the magnetic projectile 215 may be disposed entirely within the center of the sphere 302, without departing from the scope of the disclosure.

[0051] In some embodiments, the recesses 304 may be arranged in a pattern, which, in this case, resembles that of stitching on a baseball. More particularly, the pattern shown in FIGS. 3A and 3B encompasses spaced apart positions distributed along a continuous undulating path about the sphere 302. However, it should be clearly understood that any pattern of magnetic field-producing components may be used in the magnetic projectile 215, in keeping with the scope of this disclosure. Indeed, the magnets may be arranged to provide a magnetic field that extends a predetermined distance from the magnetic projectile 215, and to do so no matter the orientation of the sphere 302. The pattern depicted in FIGS. 3A and 3B may be configured to project the produced magnetic field(s) substantially evenly around the sphere 302.

[0052] The first frac actuator 210a (FIGS. 2A-2E) may be actuated based on detection of the magnetic projectile 215 or a specific pattern or sequence of magnetic projectiles 215 as detected by the sensor 212 (FIGS. 2A-2E). For example, the first frac actuator 210a may be actuated when a first magnetic projectile 215 is displaced into the fracturing assembly 200, or when a predetermined number of magnetic projectiles 215 are detected by the sensor 212. As another example, the first frac actuator 210a may be actuated in response to passage of a predetermined amount of time following detection of the particular magnetic projectile 215, a predetermined spacing in time of two or more magnetic projectiles 215, or a predetermined spacing of time between predetermined numbers of magnetic projectiles 215. Thus, conveying a pattern of magnetic projectiles 215 into the fracturing assembly 200 can be used to transmit a corresponding magnetic signal to the first frac actuator 210a.

[0053] FIGS. 4A and 4B are cross-sectional side views of an example production assembly 400, according to one or more embodiments. The production assembly 400 may be the same as or similar to the any of the production assemblies 120 of FIG. 1 and, therefore, may be included in the completion assembly 114 and used to produce fluids from the annulus 122 and originating from the surrounding subterranean formation 110 (FIG. 1). Moreover, the production assembly 400 may be used in conjunction with the above-described fracturing assembly 200 of FIGS. 2A-2E, such as being arranged in a common completion section of the completion assembly 114. FIGS. 4A-4B depict progressive views of the production assembly 400 during example operation.

[0054] In FIG. 4A, the production assembly 400 is depicted as including a base pipe 402 that defines a central flow passage 404 and one or more production ports 406 that facilitate fluid communication between the central flow passage 404 and the annulus 122. The base pipe 402 may be the same as or an axial extension of the base pipe 202 of the

fracturing assembly 200 of FIGS. 2A-2E. Accordingly, the central flow passage 404 may fluidly communicate with the central flow passage 204 (FIGS. 2A-2E) of the fracturing assembly 200 and any fluids drawn into the base pipe 402 may be conveyed into the work string 112 (FIG. 1) and transported to a surface location for collection. A filtration device 408 is arranged about the base pipe 402 and, in one embodiment, may extend from an end ring 410 arranged about the base pipe 402 to provide a mechanical interface between the base pipe 402 and the filtration device 408. In other embodiments, however, the end ring 410 may be omitted and the filtration device 408 may alternatively be coupled directly to the base pipe 402.

[0055] The filtration device 408 serves as a filter medium designed to allow fluids derived from the formation 110 (FIG. 1) to flow therethrough but substantially prevent the influx of particulate matter of a predetermined size. In some embodiments, as illustrated, the filtration device 408 may comprise one or more well screens 412 arranged about the base pipe 402. As illustrated, the well screen(s) 412 may be radially offset a short distance from the base pipe 402 and thereby define a production annulus 414 therebetween. In other embodiments, however, the well screen(s) 412 may be replaced with a slotted liner, or the like, without departing from the scope of the disclosure.

[0056] The well screen(s) 412 may be fluid-porous, particulate restricting devices made from of a plurality of layers of a wire mesh that are diffusion bonded or sintered together to form a fluid porous wire mesh screen. The well screen(s) 412 may alternatively include multiple layers of a weave mesh wire material having a uniform pore structure and a controlled pore size that is determined based upon the properties of the formation 110 (FIG. 1). In other applications, however, the well screen(s) 412 may comprise a single layer of wire mesh, multiple layers of wire mesh that are not bonded together, a single layer of wire wrap, multiple layers of wire wrap or the like, that may or may not operate with a drainage layer.

[0057] The production assembly 400 may further include a production sleeve 416 positioned for longitudinal movement within the central flow passage 404. The production ports 406 (one shown) are blocked (occluded) when the production sleeve 416 is in a first or “closed” position, thereby preventing fluid communication between the annulus 122 and the central flow passage 404. As described below, however, the production sleeve 416 is actuatable to move (i.e., displace) to a second or “open” position where the production ports 406 are exposed.

[0058] To move the production sleeve 416 to the open position, a production actuator 418 is triggered based on a wireless signal received or otherwise detected by a production sensor 420. The production sensor 420 may be similar to the sensor 212 of FIG. 2A and, therefore, may comprise at least one of a magnetic sensor, an antenna, a pressure sensor, a temperature sensor, an acoustic sensor, a vibration sensor, a strain sensor, an accelerometer, a flow meter, or any combination thereof. Moreover, the production sensor 420 is communicably connected to an electronics module 422 similar to the electronics module 214 of FIGS. 2A-2D. Accordingly, the electronics module 422 may include electronic circuitry configured to determine whether the production sensor 420 has detected a particular wireless signal, and may also include a power supply used to power operation of one or more of the electronics module 422, the production sensor 420, and the production actuator 418.

[0059] In embodiments where the production sensor 420 is a magnetic sensor, the electronic circuitry may be configured to determine whether the production sensor 420 has detected a predetermined magnetic field, a pattern or combination of magnetic fields, or another magnetic property of the magnetic projectile 215 introduced into the central flow passage 404. The magnetic projectile 215 may be pumped to or past the production sensor 420 in order to transmit a magnetic signal to the first frac actuator 210a. Similar to the electronics module 214 of FIGS. 2A-2D, the electronics module 422 may include a non-volatile memory having a database programmed with a predetermined magnetic field(s) or other magnetic properties for comparison against magnetic fields/properties exhibited by the magnetic projectile 215 and detected by the production sensor 420.

[0060] In embodiments where the production sensor 420 is a pressure sensor, predetermined pressure levels or sequences may be programmed into the memory of the electronics module 422 for comparison against an actual fluid pressure or a series (pattern) of pressure changes (fluctuations) detected in the central flow passage 404 by the production sensor 420. Accordingly, to actuate the production actuator 418, a well operator may selectively pressurize the central flow passage 404 to match one of the programmed pressure levels or sequences.

[0061] In embodiments where the production sensor 420 is a temperature sensor, a predetermined temperature level or disparity (fluctuation) may be programmed into the memory of the electronics module 422 for comparison against the real-time temperature or temperature fluctuations detected in the central flow passage 404 by the production sensor 420.

[0062] In embodiments where the production sensor 420 is an acoustic sensor, predetermined acoustic signatures or acoustic sequences may be programmed into the memory of the electronics module 422 for comparison against noises or a series (pattern) of noise changes detected by the production sensor 420. Such noises may be generated, for example, by axially translating and/or rotating a pipe string or other downhole tool within the wellbore. In other embodiments, however, the noises may comprise acoustic signals transmitted to the production sensor 420 from a remote location, such as the well surface. In yet other embodiments, the noise may be generated by fluid movement.

[0063] If the electronics module 422 determines that the production sensor 420 has detected a predetermined wireless signal, the electronic circuitry triggers actuation of the production actuator 418 to cause the production sleeve 416 to move to the open position and thereby expose the production ports 406. In some embodiments, as illustrated, the production actuator 418 may be similar to one or both of the first and second frac actuators 210a,b of FIGS. 2A-2E. More specifically, the production actuator 418 includes a piercing member 424 configured to pierce a pressure barrier 426 that initially separates a first chamber 428a and a second chamber 428b defined by the base pipe 402. When the production sensor 420 detects the predetermined wireless signal, the piercing member 424 is triggered to pierce the pressure barrier 426, and a support fluid 430 (e.g., oil) flows from the first chamber 428a to the second chamber 428b, which generates a pressure differential across the production sleeve 416. The generated pressure differential urges the production sleeve 416 to move (displace) toward the open position.

[0064] In FIG. 4B, the production actuator 418 is shown actuated as the piercing member 424 has pierced the pressure barrier 426 such that the support fluid 430 in the first chamber 428a is able to escape into the second chamber 428b and the resulting pressure differential has moved the production sleeve 416 to the open position. In the open position, a fluid 432 from the annulus 122 may be drawn through the filtration device 408 and into the production annulus 414. The fluid 432 may traverse the exterior of the base pipe 402 within the production annulus 414 until locating the production ports 406, which allow the fluid 432 to enter the central flow passage 404 for production to the well surface.

[0065] In some embodiments, actuation of the production sleeve 416 may be time delayed. More specifically, the electronic circuitry of the electronics module 422 may include a timer that may be triggered (started) upon detection of the predetermined wireless signal with the production sensor 420. The timer may be programmed with a predetermined time period for actuating the production actuator 418 and, upon expiration of the

predetermined time period, the electronics module 422 may send a signal that actuates (operates) the production actuator 418. The predetermined time period may provide sufficient time to accomplish the preceding hydraulic fracturing operations described above with reference to the fracturing assembly 200 of FIGS. 2A-2E. The predetermined time
5 period may be about 6 hours, about 12 hours, about 24 hours, about 48 hours, more than 48 hours, or any time range falling therebetween.

[0066] FIG. 5 is an isometric view of an example completion section 500 that may form part of the completion assembly 114 of FIG. 1, according to one or more embodiments. The completion section 500 may be generally located between axially adjacent wellbore
10 packers 116 (FIG. 1) and include a fracturing assembly 118 and a production assembly 120 axially offset from the fracturing assembly 118. The production assembly 120 includes a plurality of filtration devices 502 used to prevent the influx of particulate matter of a predetermined size. In the illustrated embodiment, the filtration devices 502 are in the form of slotted liners 502, but could alternatively comprise sand screens or another type of
15 downhole filtration system, without departing from the scope of the disclosure.

[0067] FIG. 6A is a partial cross-sectional side view of the fracturing assembly 118 of FIG. 5, according to one or more embodiments. As mentioned above, the fracturing assembly 118 may be used to inject a fluid into the annulus 122 defined between the completion assembly 114 (FIG. 1) and the wellbore 102 (FIG. 1). The fracturing assembly
20 118 includes a base pipe 602 that defines a central flow passage 604 in fluid communication with the work string 112 (FIG. 1) such that fluids and objects (e.g., wellbore projectiles) conveyed into the wellbore 102 via the work string 112 will communicate with (flow into) the central flow passage 604.

[0068] The fracturing assembly 118 further includes a frac sleeve 606 positioned for
25 longitudinal movement within the central flow passage 604. One or more injection ports 608 (two shown) are defined in the wall of the base pipe 602 200 and are blocked (occluded) when the frac sleeve 606 is in a first or “closed” position, thereby preventing fluid communication between the annulus 122 and the central flow passage 604. As discussed below, the frac sleeve 606 is actuatable to move (i.e., displace) to a second or “open” position
30 where fluid communication between the annulus 122 and the central flow passage 604 is facilitated. In the illustrated embodiment, fluid communication is facilitated by aligning one or more frac ports 610 defined in the frac sleeve 606 with the injection ports 608.

[0069] In some embodiments, as illustrated, the frac sleeve 606 may comprise two sleeve sections, shown as an upper sleeve section 612a and a lower sleeve section 612b. As

illustrated, the frac ports 610 are defined in the lower sleeve section 612b. Moreover, as described below, the upper and lower sleeve sections 612a,b may be able to translate a short distance relative to one another within the central flow passage 604.

[0070] The fracturing assembly 118 further includes a first frac actuator 614a and a second frac actuator 614b. To move the frac sleeve 606 to the open position, the first frac actuator 614a is triggered, and to move the frac sleeve 606 back to the closed position, the second frac actuator 614b is triggered. The first frac actuator 614a may be triggered based on a wireless signal detected by a first sensor 616a coupled to the wall of the base pipe 602. The first sensor 616a may be similar to the sensor 212 of FIG. 2A and, therefore, may comprise at least one of a magnetic sensor, an antenna, a pressure sensor, a temperature sensor, an acoustic sensor, a vibration sensor, a strain sensor, an accelerometer, a flow meter, or any combination thereof. While the first sensor 616a is shown located downhole from the frac sleeve 606, the first sensor 616a could alternatively be located uphole from the frac sleeve 606, without departing from the scope of the disclosure.

[0071] The first sensor 616a may be communicably connected to an electronics module 618 similar to the electronics module 214 of FIGS. 2A-2D. Accordingly, the electronics module 618 may include electronic circuitry configured to determine whether the first sensor 616a has detected a particular wireless signal, and may also include a power supply used to power operation of one or more of the electronics module 618, the first sensor 616a, and the first frac actuator 614a.

[0072] In embodiments where the first sensor 616a is a magnetic sensor, the electronic circuitry may be configured to determine whether the first sensor 616a has detected a predetermined magnetic field, a pattern or combination of magnetic fields, or another magnetic property of a magnetic projectile 620 introduced into the central flow passage 404.

The magnetic projectile 620 may be the same as or similar to the magnetic projectile 215 of FIGS. 2A and 4A and, therefore, may comprise a ball, a dart, a plug, a fluid, a gel, a pill or slurry of magnetic particles, or any other device or substance that exhibits a magnetic property detectable by the first sensor 616a. The electronics module 618 may also include a non-volatile memory having a database programmed with a predetermined magnetic field(s) or other magnetic properties for comparison against magnetic fields/properties exhibited by the magnetic projectile 620 and detected by the first sensor 616a.

[0073] In embodiments where the first sensor 616a is a pressure sensor, a temperature sensor, or an acoustic sensor, actuation of the first frac actuator 614a may be triggered and

otherwise undertaken as generally described above with reference to operation of the sensor 212 of FIG. 2A and, therefore, will not be described again.

[0074] FIGS. 6B and 6C are enlarged cross-sectional side views of the first and second frac actuators 614a,b, respectively, as indicated by the dashed boxes of FIG. 6A.

5 Similar to the actuators discussed above, the first and second frac actuators 614a,b can each comprise any type of actuator (e.g., electrical, hydraulic, mechanical, explosive, chemical, a combination thereof, etc.) used to advance a piercing member towards a pressure barrier upon actuation. In FIG. 6B, for example, the first frac actuator 614a includes a piercing member 622 operable to pierce a pressure barrier 624 that initially separates a first chamber 626a and
10 a second chamber 626b each defined in the base pipe 602. When the first sensor 616a detects the predetermined wireless signal, a command signal may be sent to the first frac actuator 614a to pierce the pressure barrier 624 with the piercing member 622, which allows a support fluid (e.g., oil) to flow from the first chamber 626a to the second chamber 626b and generate a pressure differential across the frac sleeve 606. The generated pressure differential urges
15 the frac sleeve 606 to move (displace) toward the open position (i.e., to the right in FIGS. 6A and 6B).

[0075] In FIG. 6C, the second frac actuator 614b also includes a piercing member 628 operable to pierce a pressure barrier 630 that initially separates a third chamber 626c and a fourth chamber 626d each defined in the base pipe 602. In some embodiments, the second
20 frac actuator 614b may be actuated when a second sensor 616b detects a predetermined wireless signal. The second sensor 616b may be similar to the first sensor 616a and, therefore, may comprise at least one of a magnetic sensor, an antenna, a pressure sensor, a temperature sensor, an acoustic sensor, a vibration sensor, a strain sensor, an accelerometer, a flow meter, or any combination thereof. Moreover, the second sensor 616b may be
25 communicably coupled to an electronics module (not shown) associated with the second frac actuator 614b.

[0076] In other embodiments, however, the second frac actuator 614b may be communicably coupled to the electronics module 618 (FIGS. 6A and 6B) of the first frac actuator 614a (FIGS. 6A and 6B) and may operate based on a time delay. More specifically,
30 the electronic circuitry of the electronics module 618 may include a timer that may be triggered (started) upon detection of the predetermined wireless signal used to actuate the first frac actuator 614a. The timer may be programmed with a predetermined time period for actuating the second frac actuator 614b and, upon expiration of the predetermined time period, the electronics module 618 may send a command signal to actuate (operate) the

second frac actuator 614b. The predetermined time period may be programmed to provide sufficient time to accomplish the hydraulic fracturing operations. For example, the predetermined time period may be about 6 hours, about 12 hours, about 24 hours, about 48 hours, more than 48 hours, or any time range falling therebetween. When the predetermined
5 time period expires, the piercing member 628 is actuated to pierce the pressure barrier 630, and a support fluid (e.g., oil) flows from the third chamber 626c to the fourth chamber 626d, which generates a pressure differential across the frac sleeve 606. The generated pressure differential urges the frac sleeve 606 to move (displace) uphole (i.e., to the left in FIGS. 6 and 6B) and thereby back to the closed position.

10 [0077] Operation of the fracturing assembly 118 will now be provided with reference to FIGS. 6A, 6D, and 6E, which depict progressive views of the fracturing assembly 118 during example operation. In FIG. 6A, the fracturing assembly 118 is shown in the closed position, where the frac sleeve 606 occludes the injection ports 608 and thereby prevents fluid communication between the annulus 122 and the central flow passage 604. Once the
15 predetermined wireless signal is detected by the first sensor 616a, however, the first frac actuator 614a may be triggered to move the frac sleeve 606 toward the open position (i.e., to the right in FIG. 6A).

[0078] In some embodiments, as illustrated, the fracturing assembly 118 may further include an isolation device 632 positioned within the central flow passage 604 and used to
20 isolate the fracturing assembly 118 from downhole portions of the completion section 500 (FIG. 5). In the illustrated embodiment, the isolation device 632 is in the form of a collapsible sand trap or diverter coupled to the distal end of the frac sleeve 606. The sand diverter is depicted in FIG. 6A in an open position that allows fluid communication through the central flow passage 604. Upon moving the frac sleeve 606 to the closed position,
25 however, the sand diverter may be configured to collapse radially and at least partially seal the central flow passage 606, as described below.

[0079] In FIG. 6D, the first frac actuator 614a is shown actuated, as described above, and the resulting pressure differential across the frac sleeve 606 has moved the frac sleeve 606 to the open position where the injection ports 608 are exposed via the frac ports 610
30 defined in the frac sleeve 606. In the illustrated embodiment, moving the frac sleeve 606 to the open position moves the lower sleeve section 612b while the upper sleeve section 612a remains relatively stationary. In other embodiments, however, the frac sleeve 606 may comprise a monolithic structure that moves as a unitary sleeve construction, without departing from the scope of the disclosure.

[0080] Moving the frac sleeve 606 to the open position may also result in full or partial isolation of the central flow passage 604 below the injection ports 608 as the isolation device 632 collapses to its closed position. As indicated above, the isolation device 632 may comprise a sand diverter. As the frac sleeve 606 moves to the right in FIG. 6D and toward the open position, the sand diverter will eventually engage a radial shoulder 634 configured to deflect and collapse the sand diverter. In some embodiments, the sand diverter may provide a seal within the central flow passage 604. In other embodiments, however, the sand diverter may simply prevent passage of particulate matter. The sand diverter may prove advantageous in vertical wells, for example, where sand, proppant, and gravel particulates from a gravel slurry or fracturing fluid might migrate downhole past the fracturing assembly 118 during a hydraulic fracturing operation. The sand diverter may serve to prevent migration of such particulate matter.

[0081] With the frac sleeve 606 in the open position, a fluid (e.g., a fracturing fluid, a gravel slurry, etc.) may then be flowed to the fracturing assembly 118 and into the central flow passage 604 at an elevated pressure to be injected into the annulus 122 via the exposed injection ports 608.

[0082] After hydraulic fracturing operations have finished, it may be desired to move the frac sleeve 606 back to the closed position in preparation for production operations undertaken by the production assembly 120 (FIG. 5) or in preparation for fracturing operations of another zone in the wellbore. To accomplish this, the second frac actuator 614b may be actuated as generally described above. In some embodiments, as discussed above, actuation of the second frac actuator 614b may be time delayed following detection of the first wireless signal by the first sensor 612a. In other embodiments, actuation of the second frac actuator 614b may be triggered following detection of a second or additional wireless signal detected by the second sensor 616b. In yet other embodiments, actuation of the second frac actuator 614b may be triggered following detection of the second wireless signal detected by the second sensor 616b and after a predetermined time delay sufficient to allow the fracturing operation to conclude.

[0083] In FIG. 6E, the frac sleeve 606 is shown moved back to the closed position following actuation of the second frac actuator 614b, as generally described above. In the illustrated embodiment, moving the frac sleeve 606 to the closed position first moves the upper sleeve section 612a, which eventually engages a portion of the lower sleeve section 612b at a radial shoulder 636 and thereafter pulls the lower sleeve section 612b as well.

Again, in other embodiments, the frac sleeve 606 may comprise a monolithic structure that moves as a unitary sleeve construction, without departing from the scope of the disclosure.

[0084] As the frac sleeve 606 moves back to the closed position, the isolation device 632 moves out of engagement with the radial shoulder 634 and allows the isolation device 632 to radially expand once again to the open position. Radial expansion of the isolation device 632 may be facilitated through one or more torsion springs associated with the isolation device 632. In other embodiments, however, the isolation device 232 may alternatively be made of a degradable material (e.g., any of the degradable materials mentioned above) that allows the isolation device 232 to dissolve over time and thereby clear the central flow passage 604 for subsequent fluid flow through the fracturing assembly 118.

[0085] FIG. 7A is a partial cross-sectional side view of the production assembly 120 of FIG. 5, according to one or more embodiments. As mentioned above, the production assembly 120 may be used to produce fluids from the annulus 122 and originating from the surrounding subterranean formation 110 (FIG. 1). The production assembly 120 is depicted as including a base pipe 702 that defines a central flow passage 704 and one or more production ports 706 that facilitate fluid communication between the central flow passage 704 and the annulus 122. The base pipe 702 may be the same as or an axial extension of the base pipe 602 of the fracturing assembly 118 of FIGS. 6A-6E. Accordingly, the central flow passage 704 may fluidly communicate with the central flow passage 604 (FIGS. 2A-2E) of the fracturing assembly 118 and any fluids drawn into the base pipe 702 may be conveyed into the work string 112 (FIG. 1) and transported to a surface location for collection.

[0086] One of the filtration devices 502 of FIG. 5 is depicted in FIG. 7A as arranged about the base pipe 702. The filtration device 502 serves as a filter medium designed to allow fluids derived from the surrounding formation 110 (FIG. 1) to flow therethrough but substantially prevent the influx of particulate matter of a predetermined size. As illustrated, the filtration device 502 may be radially offset a short distance from the base pipe 702 and thereby define a production annulus therebetween.

[0087] The production assembly 120 further includes a production sleeve 708 positioned for longitudinal movement within the central flow passage 704. The production ports 706 (one shown) are blocked (occluded) when the production sleeve 708 is in a first or "closed" position, thereby preventing fluid communication between the annulus 122 and the central flow passage 704. The production sleeve 708, however, is actuatable to move (i.e., displace) to a second or "open" position where the production ports 706 are exposed via one or more influx ports 710 defined in the production sleeve 708.

[0088] To move the production sleeve 708 to the open position, a production actuator 712 is triggered based on a wireless signal. In some embodiments, the wireless signal may be the same wireless signal used to actuate the first frac actuator 614a of FIGS. 6A-6E, and actuation of the production actuator 712 may be based on a time delay sufficient to allow the hydraulic fracturing operations to terminate. In such embodiments, the production actuator 712 may be communicably coupled to the electronics module 618 (FIGS. 6A and 6B). In other embodiments, however, the wireless signal may comprise a second or additional wireless signal received or otherwise detected by a production sensor 714. The production sensor 714 may be similar to the sensor 212 of FIG. 2A and, therefore, may comprise at least one of a magnetic sensor, an antenna, a pressure sensor, a temperature sensor, an acoustic sensor, a vibration sensor, a strain sensor, an accelerometer, a flow meter, or any combination thereof. While the production sensor 714 is shown located downhole from the production sleeve 708, the production sensor 714 could alternatively be located uphole from the production sleeve 708, without departing from the scope of the disclosure.

[0089] The production sensor 714 may be communicably connected to an electronics module 716 similar to the electronics module 214 of FIGS. 2A-2D. Accordingly, the electronics module 716 may include electronic circuitry configured to determine whether the production sensor 714 has detected a particular wireless signal, and may also include a power supply used to power operation of one or more of the electronics module 716, the production sensor 714, and the production actuator 712.

[0090] In embodiments where the production sensor 714 is a magnetic sensor, the electronic circuitry may be configured to determine whether the production sensor 714 has detected a predetermined magnetic field, a pattern or combination of magnetic fields, or another magnetic property of a magnetic projectile 718 introduced into the central flow passage 704. The magnetic projectile 718 may be the same as or similar to the magnetic projectile 620 of FIG. 6A and, therefore will not be described again. The electronics module 716 may also include a non-volatile memory having a database programmed with a predetermined magnetic field(s) or other magnetic properties for comparison against magnetic fields/properties exhibited by the magnetic projectile 718 and detected by the production sensor 714.

[0091] In embodiments where the production sensor 714 is a pressure sensor, a temperature sensor, or an acoustic sensor, actuation of the production actuator 712 may be triggered and otherwise undertaken as generally described above with reference to operation of the sensor 212 of FIG. 2A and, therefore, will not be described again.

[0092] If the electronics module 716 determines that the production sensor 714 has detected a predetermined wireless signal, the electronic circuitry triggers actuation of the production actuator 712 to cause the production sleeve 708 to move to the open position and thereby expose the production ports 706.

5 [0093] FIG. 7B is an enlarged cross-sectional side view of the production actuator 712, according to one or more embodiments. As illustrated, the production actuator 712 includes a piercing member 720 configured to pierce a pressure barrier 722 that initially separates a first chamber 724a and a second chamber 724b defined by the base pipe 702. When the production sensor 714 detects the predetermined wireless signal (or when a
10 command signal is sent to the production actuator 712 from the electronics module 618 of FIGS. 6A and 6B), the production actuator 712 is actuated to penetrate the pressure barrier 722 with the piercing member 720. Penetrating the pressure barrier 722 allows a support fluid (e.g., oil) to flow from the first chamber 724a to the second chamber 724b, which generates a pressure differential across the production sleeve 708, and the generated pressure
15 differential urges the production sleeve 708 to move (displace) toward the open position.

[0094] FIG. 7C is a cross-sectional side view of the production assembly 120 with the production sleeve 708 moved to the open position. The production actuator 712 is shown actuated in FIG. 7C and the production sleeve 708 has moved within the central flow passage 704 to the open position where the influx ports 710 align with the production ports 706. In
20 the open position, fluids from the annulus 122 may be drawn through the filtration device 502 and into the production annulus until locating the production ports 706, which allow the fluid to enter the central flow passage 704 via the influx ports 710 for production to the well surface.

[0095] FIGS. 8A and 8B are cross-sectional side views of an alternate embodiment of
25 the fracturing assembly 118 of FIGS. 6A-6E. Similar to the embodiment of FIGS. 6A-6E, the fracturing assembly 118 includes the frac sleeve 606, the first and second frac actuators 614a,b, and at least the first sensor 616a (alternately including also the second sensor 616b). Unlike the embodiment of FIGS. 6A-6E, however, the fracturing assembly 118 may further include an isolation device 802 in the form of a flapper or flapper valve. The isolation device
30 802 is positioned within the central flow passage 604 and used to isolate the fracturing assembly 118 from downhole portions of the completion section 500 (FIG. 5). In some embodiments, the isolation device 802 may be coupled to the distal end of the frac sleeve 606 at a pivot point 804, such as a torsion spring. In other embodiments, however, the isolation

device 802 may be coupled to or otherwise carried by the base pipe 602, without departing from the scope of the disclosure.

[0096] In FIG. 8A, the isolation device 802 is depicted in an open position that allows fluid communication through the central flow passage 604. Upon moving the frac sleeve 606 to the closed position, however, the flapper isolation device 802 may be configured to pivot at the pivot point 804 to a closed position and at least partially seal the central flow passage 606.

[0097] In FIG. 8B, the frac sleeve 606 has moved to the open position where the injection ports 608 are exposed via the frac ports 610 defined in the frac sleeve 606. Moving the frac sleeve 606 to the open position also results in full or partial isolation of the central flow passage 604 below the injection ports 608 as the isolation device 802 pivots to the closed position. More particularly, as the frac sleeve 606 moves to the right in FIG. 8D and toward the open position, the distal end of the flapper isolation device 802 will eventually engage the radial shoulder 634, which deflects the flapper to its closed position. Upon moving the frac sleeve 606 back to the closed position, as described above, the flapper isolation device 802 may be configured to pivot back to the open position. In such embodiments, the torsion spring at the pivot point 804 may provide the necessary force required to pivot the isolation device 802 to the open position.

[0098] Embodiments are also contemplated herein where the isolation device 802 (in any form) is entirely omitted from the fracturing assembly 118. In such embodiments, the fracturing and production assemblies 118, 120 may operate as generally described herein, an hydraulic fracturing at the fracturing assembly 118 may be undertaken since the remaining fracturing assemblies in the completion string 114 (FIG. 1) will be closed and the distal end of the completion string 114 will also be closed. Consequently, the hydraulic pressure required for the fracturing operation can occur without the need for an isolation device 802 (in any form) used to isolate the fracturing assembly 118 from downhole portions of the completion string 114. In such embodiments, a well operator may be able to fracture and produce desired portions of a surrounding subterranean formation 110 (FIG. 1) by selectively actuating desired fracturing and completion assemblies 118, 120.

[0099] Embodiments are also contemplated herein where an intervention or shifting tool may be used to manually (physically) shift one or both of the frac and production sleeves between open and closed positions. This may be required in the event an associated actuation device fails or is otherwise unable to properly actuate the frac and production sleeves, such as when debris or other downhole obstructions prevent proper actuation. In such embodiments,

the frac and production sleeves described herein will have corresponding shifting profiles configured to receive a profile of the shifting tool. Once the profiles mate, axial loads may be applied on the frac and production sleeves to move between the open and closed positions.

[0100] It is noted that the frac and production actuators described herein are not limited to using piercing members configured to pierce or penetrate a pressure barrier. Rather, it is also contemplated herein to replace the described piercing members with a valve. In such embodiments, the valve may include a rod similar to the piercing members, but including one or more seals (e.g., O-rings) disposed about the rod. The rod may be extended into a conduit to generate a seal between adjacent fluid chambers. To enable fluid communication between the adjacent fluid chambers, and thereby actuate a frac sleeve or a production sleeve, the frac or production actuator may be actuated. Alternatively, the force required to push the rod out of the conduit (i.e., retract it) may be provided by fluid pressure pushing on the end of the rod.

[0101] Computer hardware used to implement the various illustrative blocks, modules, elements, components, methods, and algorithms described herein can include a processor configured to execute one or more sequences of instructions, programming stances, or code stored on a non-transitory, computer-readable medium. The processor can be, for example, a general purpose microprocessor, a microcontroller, a digital signal processor, an application specific integrated circuit, a field programmable gate array, a programmable logic device, a controller, a state machine, a gated logic, discrete hardware components, an artificial neural network, or any like suitable entity that can perform calculations or other manipulations of data. In some embodiments, computer hardware can further include elements such as, for example, a memory (e.g., random access memory (RAM), flash memory, read only memory (ROM), programmable read only memory (PROM), erasable read only memory (EPROM)), registers, hard disks, removable disks, CD-ROMs, DVDs, or any other like suitable storage device or medium.

[0102] Executable sequences described herein can be implemented with one or more sequences of code contained in a memory. In some embodiments, such code can be read into the memory from another machine-readable medium. Execution of the sequences of instructions contained in the memory can cause a processor to perform the process steps described herein. One or more processors in a multi-processing arrangement can also be employed to execute instruction sequences in the memory. In addition, hard-wired circuitry can be used in place of or in combination with software instructions to implement various

embodiments described herein. Thus, the present embodiments are not limited to any specific combination of hardware and/or software.

[0103] As used herein, a machine-readable medium will refer to any medium that directly or indirectly provides instructions to a processor for execution. A machine-readable medium can take on many forms including, for example, non-volatile media, volatile media, and transmission media. Non-volatile media can include, for example, optical and magnetic disks. Volatile media can include, for example, dynamic memory. Transmission media can include, for example, coaxial cables, wire, fiber optics, and wires that form a bus. Common forms of machine-readable media can include, for example, floppy disks, flexible disks, hard disks, magnetic tapes, other like magnetic media, CD-ROMs, DVDs, other like optical media, punch cards, paper tapes and like physical media with patterned holes, RAM, ROM, PROM, EPROM, and flash EPROM.

[0104] 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 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 elements 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.

[0105] As used herein, the phrase “at least one of” preceding a series of items, with
5 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” 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
10 combination of A, B, and C; and/or at least one of each of A, B, and C.

CLAIMS

What is claimed is:

1. A completion section for a downhole completion assembly, comprising:
a base pipe that defines a central flow passage, one or more injection ports, and one or more production ports;
a fracturing assembly including:
a frac sleeve positioned within the central flow passage adjacent the one or more injection ports;
a sensor that detects a wireless signal;
a first frac actuator actuatable in response to the wireless signal to move the frac sleeve toward an open position where the one or more injection ports are exposed; and
a second frac actuator actuatable based on the wireless signal to move the frac sleeve to a closed position where the frac sleeve occludes the one or more injection ports; and
a production assembly axially offset from the fracturing assembly and including:
a production sleeve positioned within the central flow passage adjacent the one or more production ports; and
a production actuator actuatable based on the wireless signal to move the production sleeve to an open position where the one or more production ports are exposed.
2. The completion section of claim 1, wherein the wireless signal is selected from the group consisting of a magnetic field, an electromagnetic signal, a pressure signal, a temperature signal, an acoustic signal, a fluid flowrate signal, and any combination thereof.
3. The completion section of claim 1, wherein the sensor is selected from the group consisting of a magnetic sensor, an antenna, a pressure sensor, a temperature sensor, an acoustic sensor, a vibration sensor, a strain sensor, an accelerometer, a flow meter, and any combination thereof.
4. The completion section of claim 1, wherein the wireless signal comprises a magnetic field generated by a magnetic projectile introduced into the central flow passage.
5. The completion section of claim 1, wherein actuation of the second frac actuator is triggered following expiration of a predetermined time period after detection of the wireless signal.

6. The completion section of claim 1, wherein actuation of the production actuator is triggered following expiration of a predetermined time period after detection of the wireless signal or upon detection of the additional wireless signal.

7. The completion section of claim 1, further comprising an isolation device positioned within the central flow passage to isolate the fracturing assembly from downhole portions of the completion section when the frac sleeve is moved to the open position.

8. The completion section of claim 1, wherein the fracturing assembly further includes a closure sleeve positioned within the central flow passage axially adjacent the frac sleeve, and wherein actuation of the second frac actuator causes the closure sleeve to translate within the central flow passage and move the frac sleeve to the closed position.

9. The completion section of claim 1, wherein the production assembly further includes a production sensor that detects the additional wireless signal to actuate the production actuator, the additional wireless signal being selected from the group consisting of a magnetic field, an electromagnetic signal, a pressure signal, a temperature signal, an acoustic signal, a fluid flowrate signal, and any combination thereof.

10. A method, comprising:

positioning a downhole completion within a wellbore, the downhole completion including at least one completion section that includes:

a base pipe that defines a central flow passage, one or more injection ports, and one or more production ports;

a fracturing assembly including a frac sleeve positioned within the central flow passage adjacent the one or more injection ports, a sensor, a first frac actuator, and a second frac actuator; and

a production assembly axially offset from the fracturing assembly and including a production sleeve positioned within the central flow passage adjacent the one or more production ports, and a production actuator;

detecting a wireless signal with the sensor;

actuating the first frac actuator in response to the wireless signal and thereby moving the frac sleeve toward an open position where the one or more injection ports are exposed;

actuating the second frac actuator based on the wireless signal and thereby moving the frac sleeve to a closed position where frac sleeve occludes the one or more injection ports; and

actuating the production actuator based on the wireless signal or in response to detection of an additional wireless signal to move the production sleeve to an open position where the one or more production ports are exposed.

11. The method of claim 10, wherein detecting the wireless signal with the sensor comprises:

- introducing a magnetic projectile into the central flow passage; and
- detecting a magnetic field generated by the magnetic projectile with the sensor.

12. The method of claim 10, wherein actuating the second frac actuator based on the wireless signal comprises triggering actuation of the second frac actuator upon an expiration of a predetermined time period after detection of the wireless signal.

13. The method of claim 10, wherein actuating the production actuator comprises triggering actuation of the production actuator upon an expiration of a predetermined time period after detection of the wireless signal or the additional wireless signal.

14. The method of claim 10, further comprising isolating the fracturing assembly from downhole portions of the completion section with an isolation device positioned within the central flow passage.

15. The method of claim 10, wherein the fracturing assembly further includes a closure sleeve positioned within the central flow passage axially adjacent the frac sleeve, and wherein actuating the second frac actuator comprises causing the closure sleeve to translate within the central flow passage and move the frac sleeve to the closed position.

16. The method of claim 10, wherein the production assembly further includes a production sensor, the method further comprising:

- detecting the additional wireless signal with the production sensor; and
- actuating the production actuator in response to the additional wireless signal and thereby moving the production sleeve to the open position.

17. A completion section for a downhole completion assembly, comprising:
a base pipe that defines a central flow passage, one or more injection ports, and one or more production ports;

- a fracturing assembly including:

- a frac sleeve positioned within the central flow passage adjacent the one or more injection ports;
 - a first sensor that detects a first wireless signal;

a first frac actuator actuatable in response to the first wireless signal to move the frac sleeve toward an open position where the one or more injection ports are exposed;

a second sensor that detects a second wireless signal; and

a second frac actuator actuatable in response to the second wireless signal to move the frac sleeve to a closed position where the frac sleeve occludes the one or more injection ports; and

a production assembly axially offset from the fracturing assembly and including:

a production sleeve positioned within the central flow passage adjacent the one or more production ports; and

a production actuator actuatable based on one of the first wireless signal, the second wireless signal, or a third wireless signal to move the production sleeve to an open position where the one or more production ports are exposed

18. The completion section of claim 17, wherein the first, second, and third wireless signals are selected from the group consisting of a magnetic field, an electromagnetic signal, a pressure signal, a temperature signal, an acoustic signal, a fluid flowrate signal, and any combination thereof.

19. The completion section of claim 17, wherein actuation of the production actuator is triggered following expiration of a predetermined time period after detection of the first wireless signal or the second wireless signal.

20. The completion section of claim 17, wherein the production assembly further includes a production sensor that detects the third wireless signal to actuate the production actuator.

21. A method, comprising:

positioning a downhole completion within a wellbore, the downhole completion including at least one completion section that includes:

a base pipe that defines a central flow passage, one or more injection ports, and one or more production ports;

a fracturing assembly including a frac sleeve positioned within the central flow passage adjacent the one or more injection ports, a first sensor, a first frac actuator, a second sensor, and a second frac actuator; and

a production assembly axially offset from the fracturing assembly and including a production sleeve positioned within the central flow passage adjacent the one or more production ports, and a production actuator;

detecting a first wireless signal with the first sensor and actuating the first frac actuator in response to the first wireless signal to move the frac sleeve toward an open position where the one or more injection ports are exposed;

detecting a second wireless signal with the second sensor and actuating the second frac actuator in response to the second wireless signal to move the frac sleeve to a closed position where frac sleeve occludes the one or more injection ports; and

actuating the production actuator based on one of the first wireless signal, the second wireless signal, or in response to detection of a third wireless signal to move the production sleeve to an open position where the one or more production ports are exposed.

22. The method of claim 21, wherein the first, second, and third wireless signals are selected from the group consisting of a magnetic field, an electromagnetic signal, a pressure signal, a temperature signal, an acoustic signal, a fluid flowrate signal, and any combination thereof.

23. The method of claim 21, wherein actuating the production actuator comprises triggering actuation of the production actuator upon an expiration of a predetermined time period after detection of the first wireless signal or the second wireless signal.

24. The method of claim 21, wherein the production assembly further includes a production sensor, the method further comprising:

detecting the third wireless signal with the production sensor; and

actuating the production actuator in response to the third wireless signal and thereby moving the production sleeve to the open position.

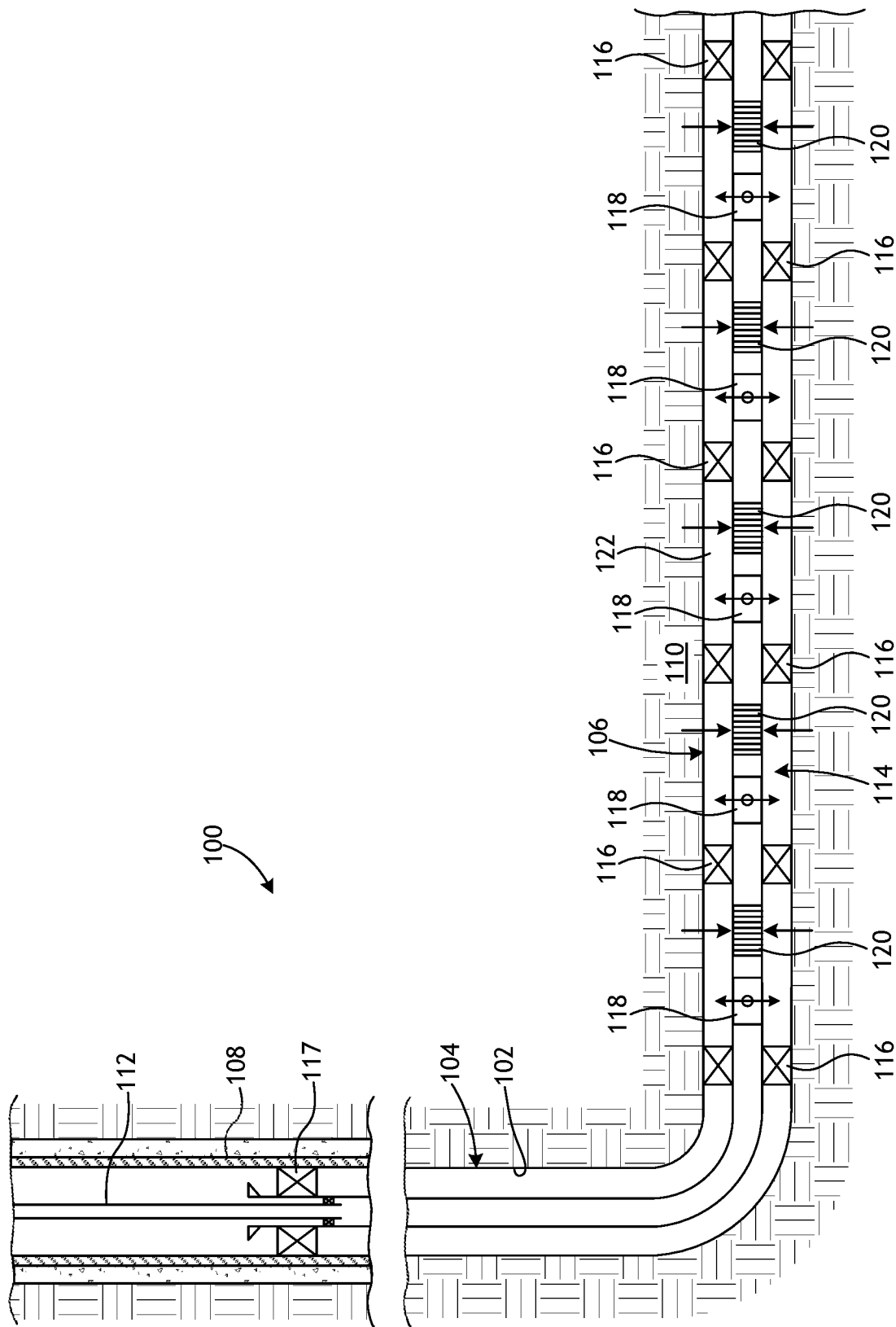


FIG. 1

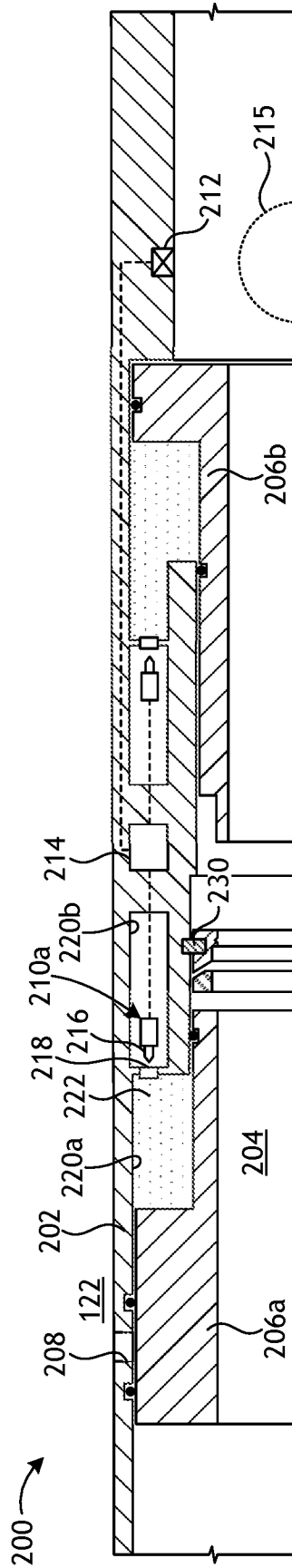


FIG. 2A

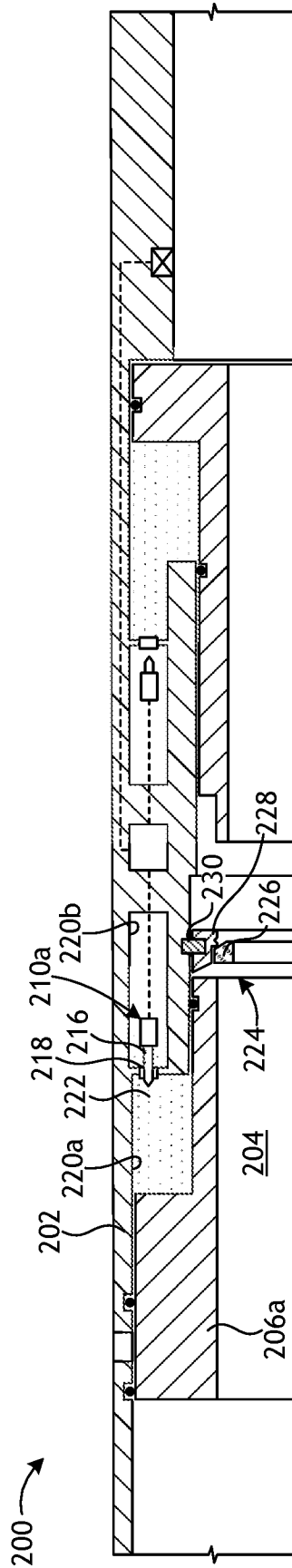


FIG. 2B

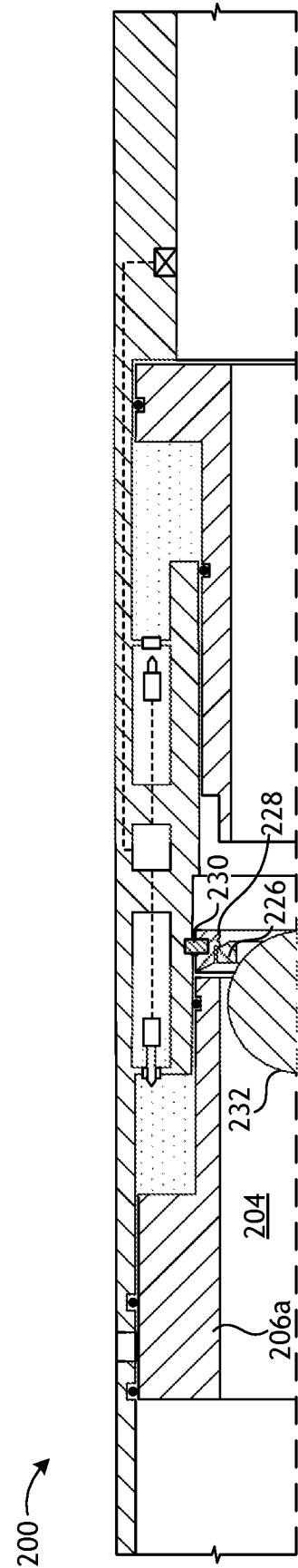


FIG. 2C

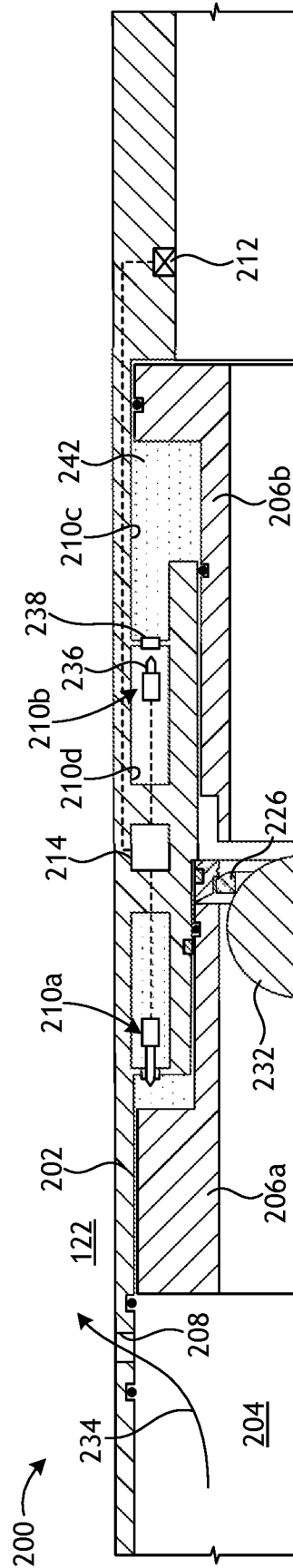


FIG. 2D

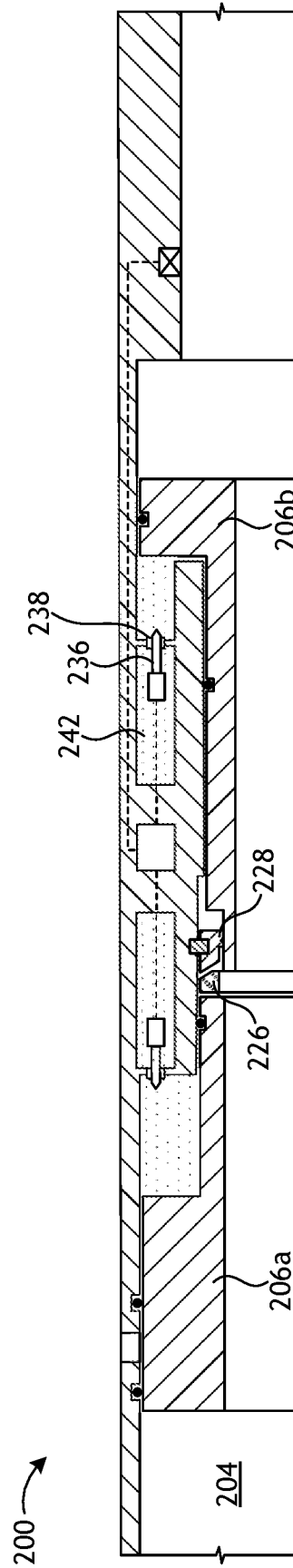


FIG. 2E

4/10

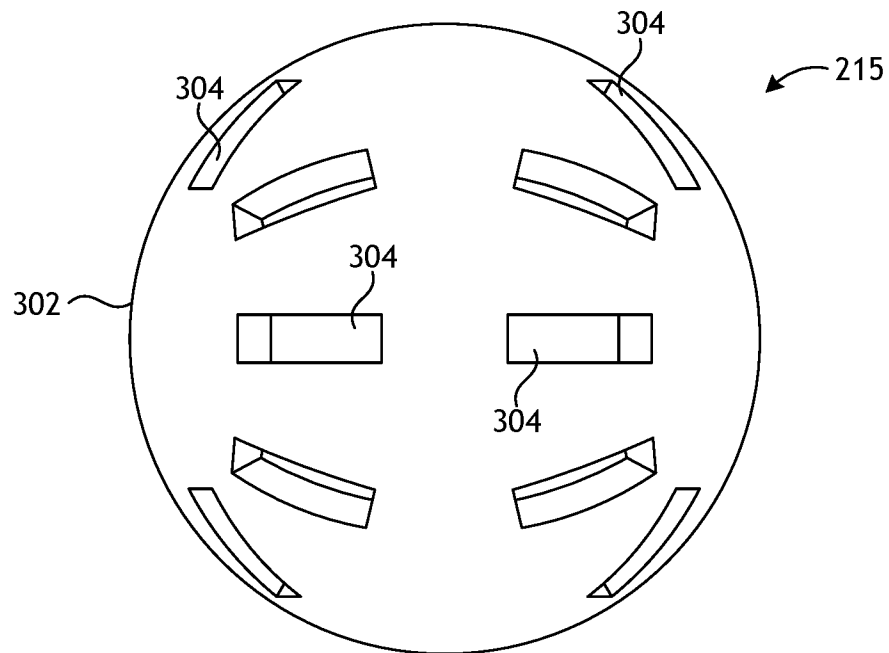


FIG. 3A

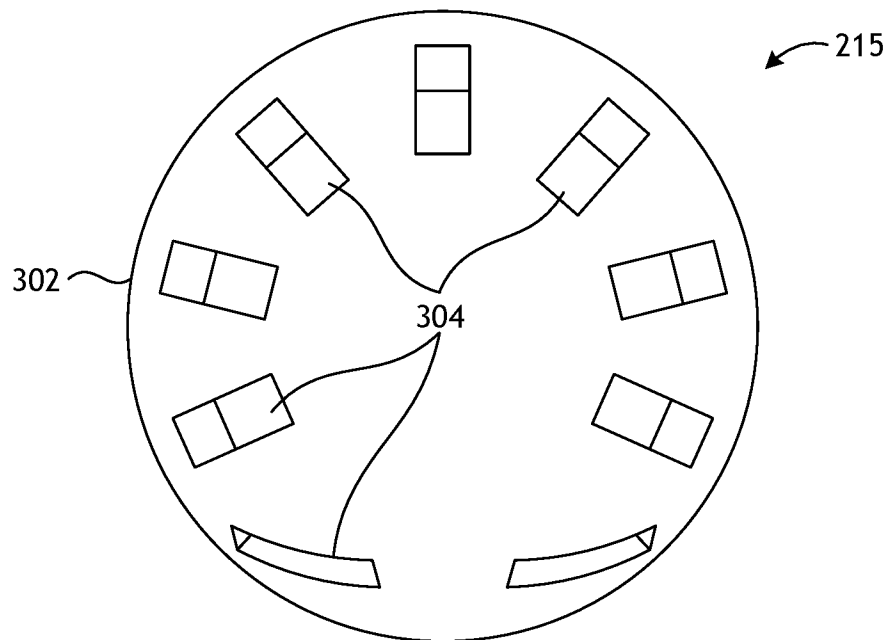


FIG. 3B

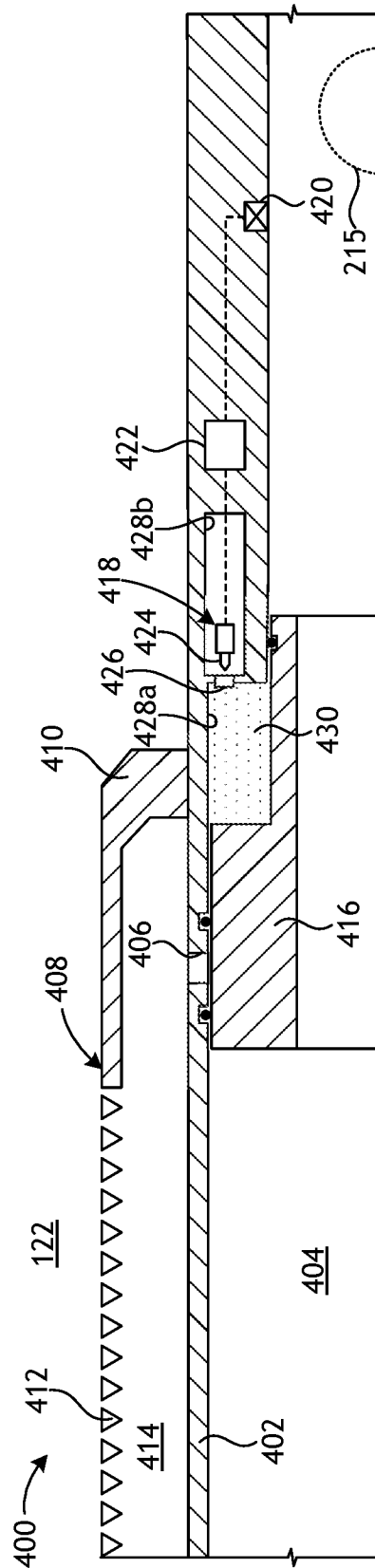


FIG. 4A

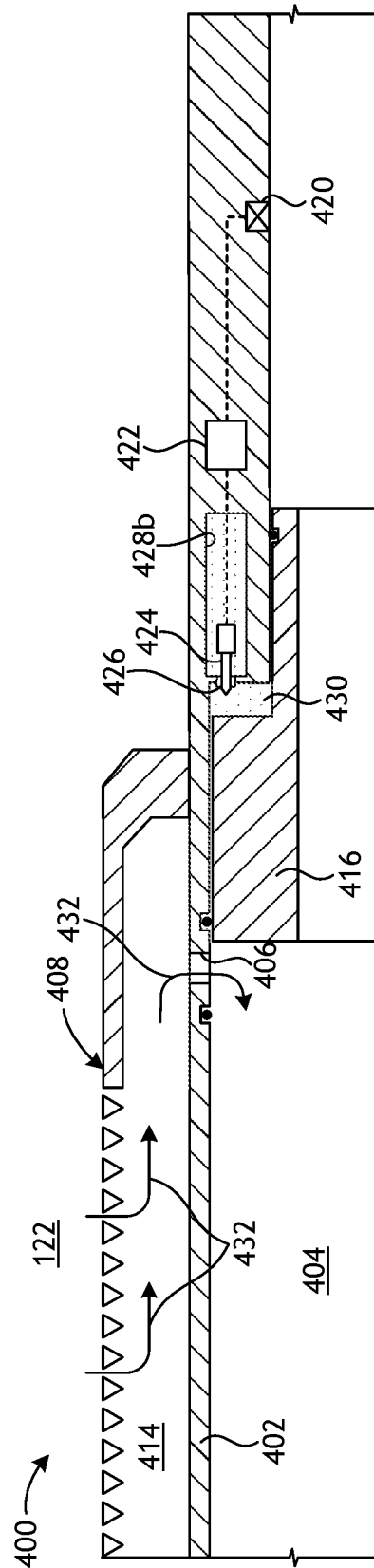


FIG. 4B

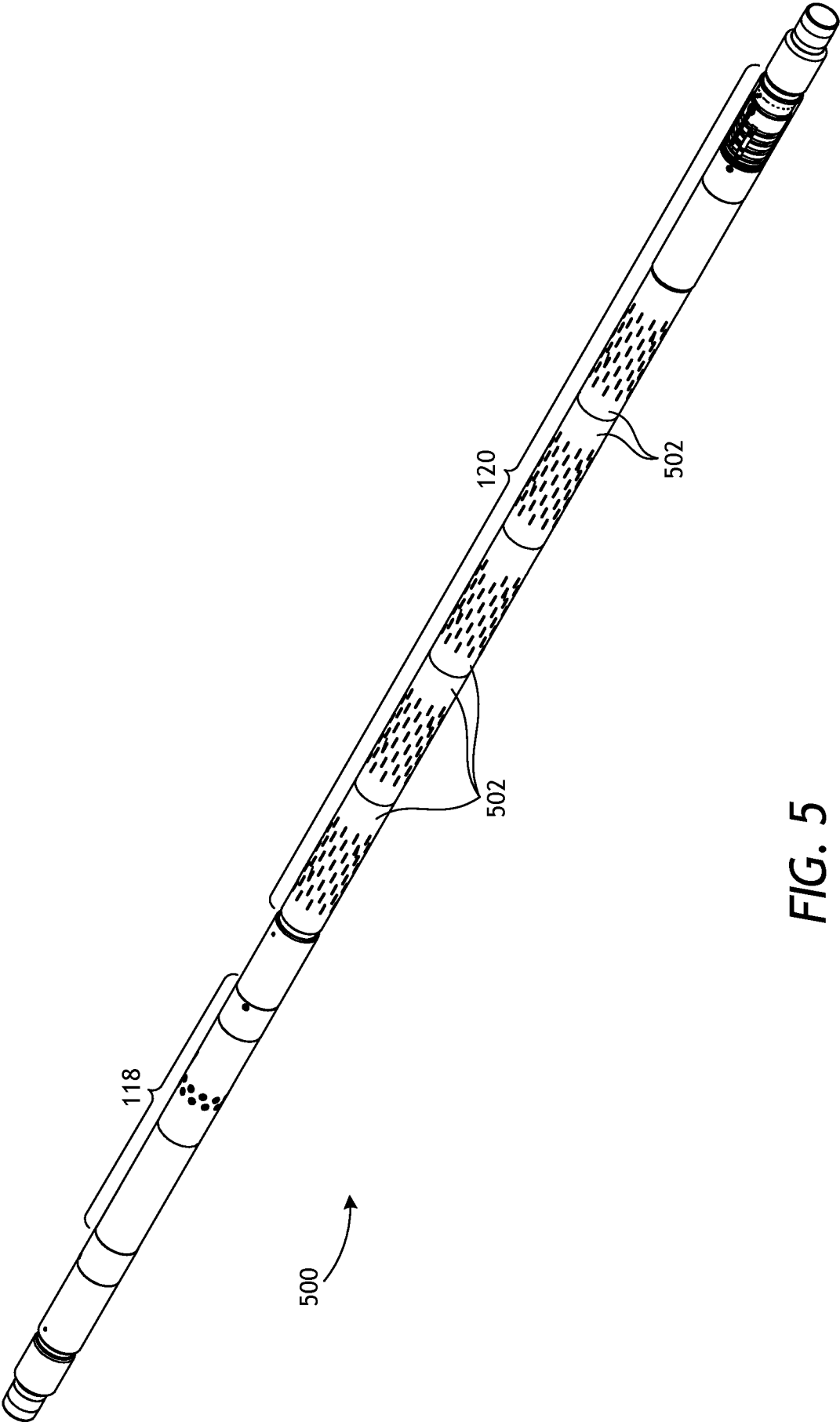


FIG. 5

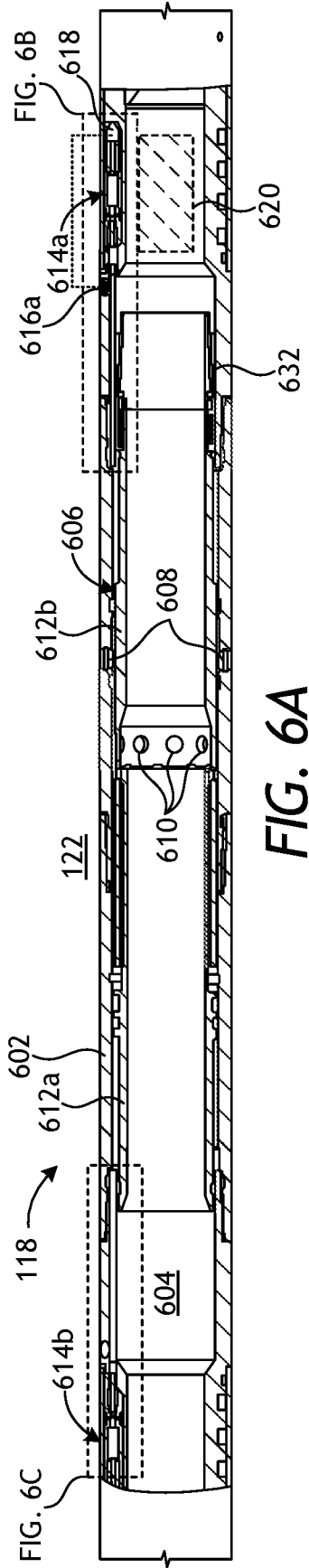


FIG. 6A

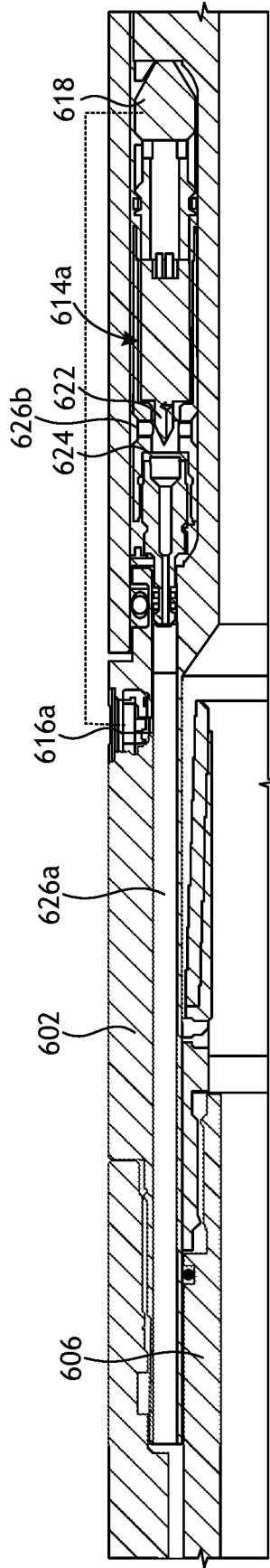


FIG. 6B

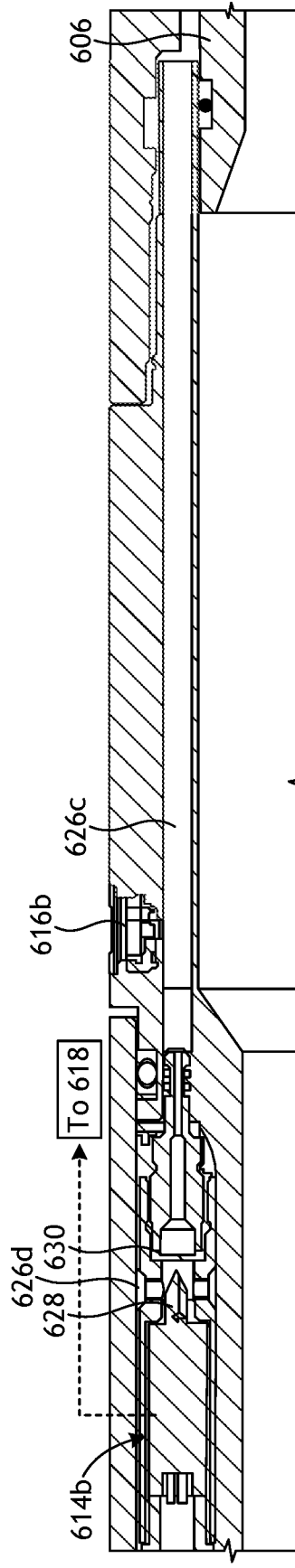


FIG. 6C

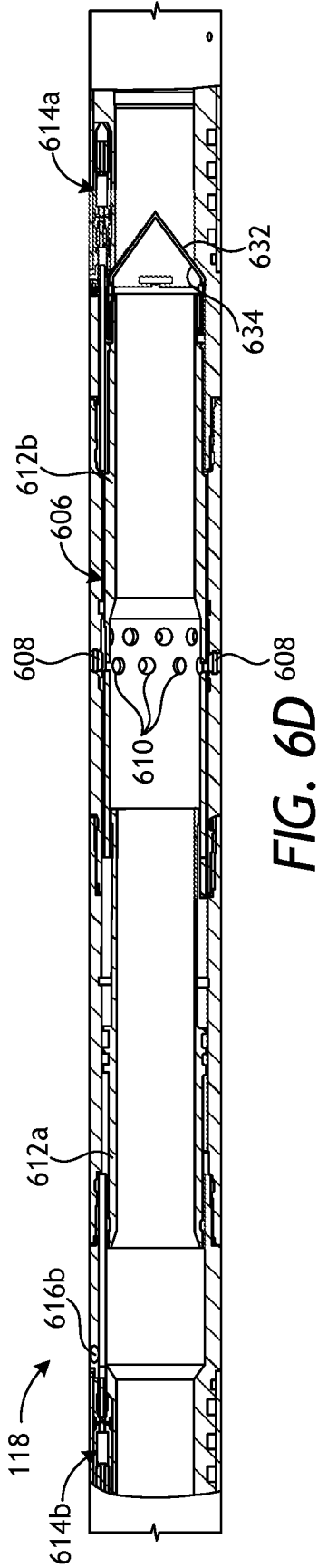


FIG. 6D

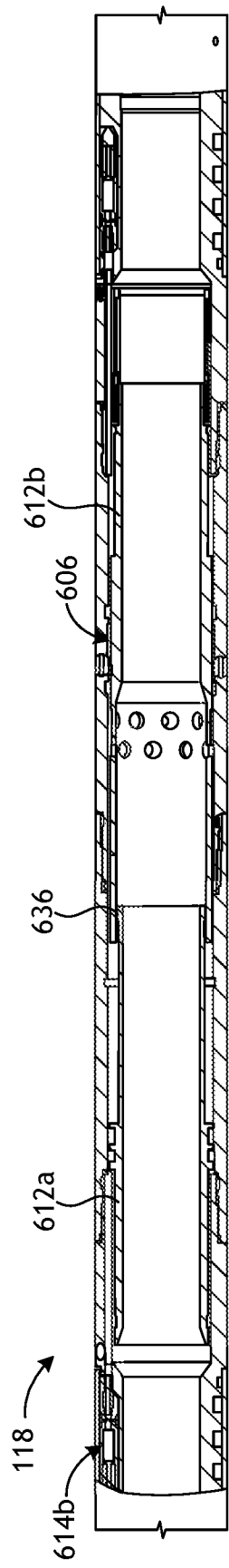
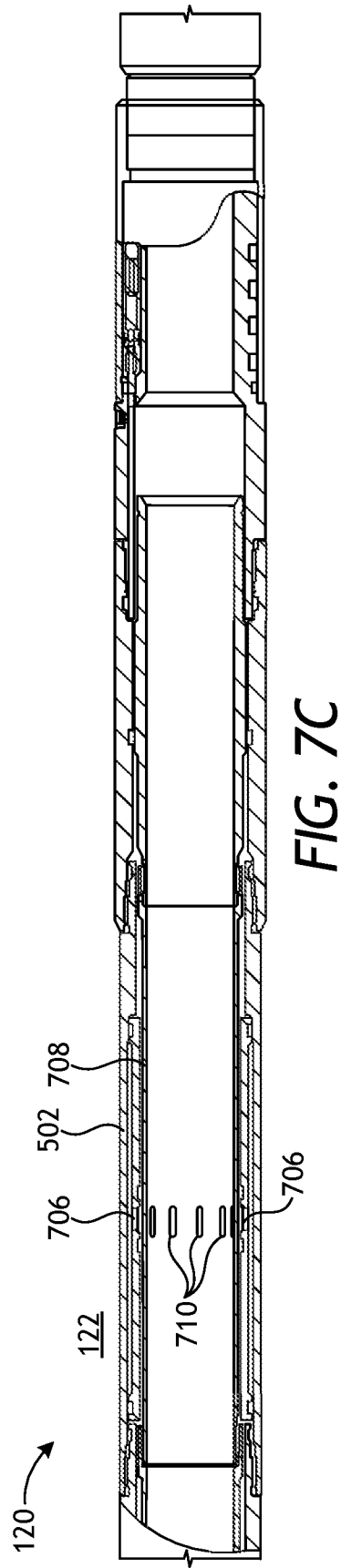
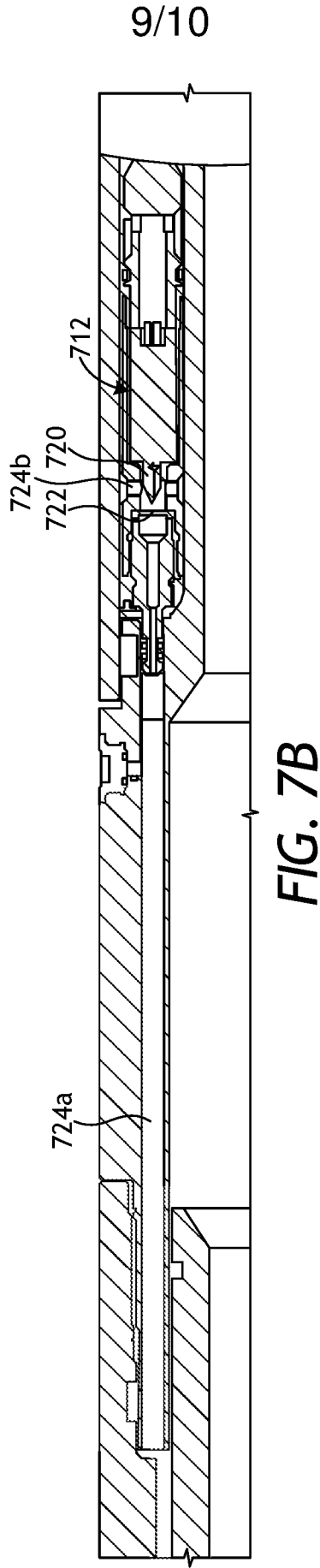
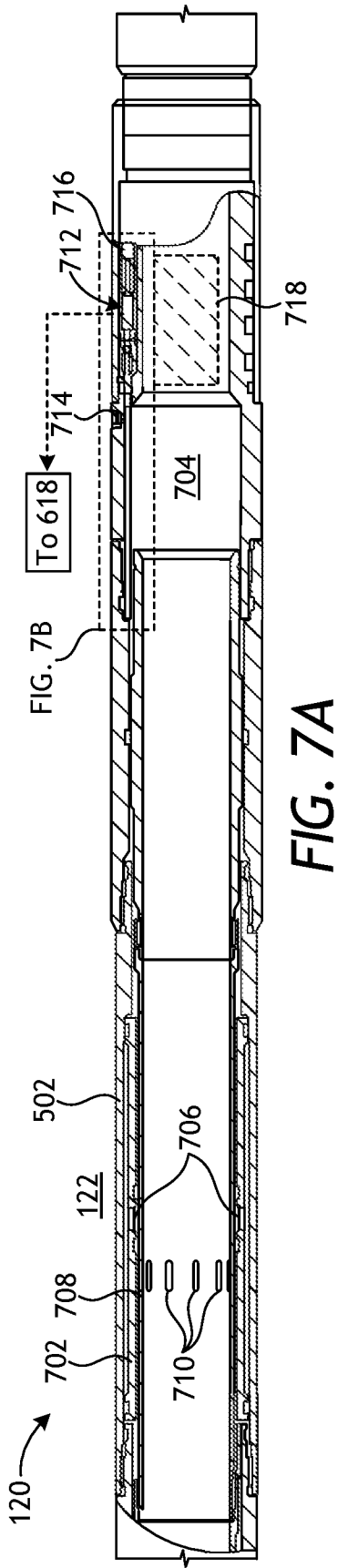


FIG. 6E



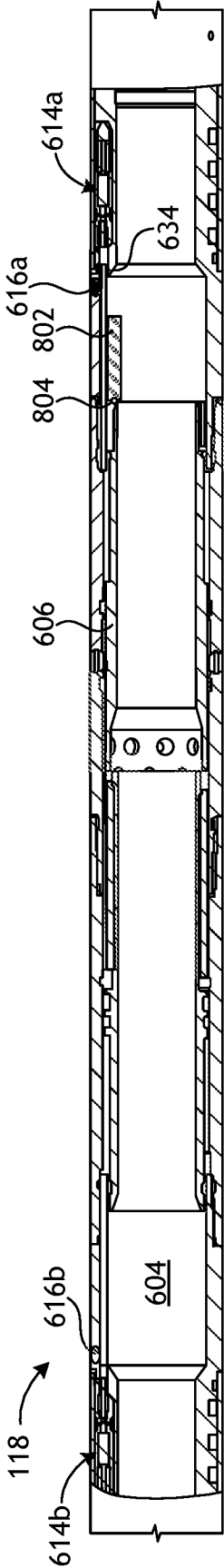


FIG. 8A

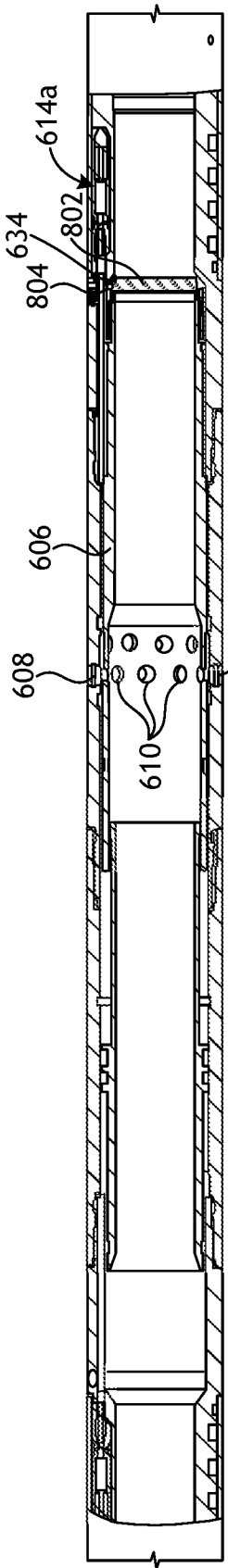


FIG. 8B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/059641**A. CLASSIFICATION OF SUBJECT MATTER****E21B 43/25(2006.01)i, E21B 43/26(2006.01)i, E21B 43/17(2006.01)i, E21B 47/12(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 43/25; E21B 43/12; E21B 47/00; E21B 34/06; E21B 33/124; E21B 34/00; E21B 43/14; E21B 43/16; E21B 43/26; E21B 43/17; E21B 47/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: completion, fracturing assembly, production assembly, frac sleeve, production sleeve, closure sleeve, sensor, actuator, wireless, magnetic field, magnetic projectile

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015-0369023 A1 (DEVON CANADA CORPORATION) 24 December 2015 See paragraphs [0056], [0061], [0115]–[0119] and figure 9.	1–24
Y	US 2014-0083689 A1 (HALLIBURTON ENERGY SERVICES, INC.) 27 March 2014 See paragraphs [0045], [0047], [0070]–[0073] and figure 9.	1–24
A	US 2014-0262240 A1 (BOONE et al.) 18 September 2014 See paragraphs [0041]–[0073] and figures 3–6.	1–24
A	US 2014-0299330 A1 (FRIPP et al.) 09 October 2014 See paragraphs [0029]–[0032] and figure 1.	1–24
A	US 2012-0061095 A1 (CAPDEROU, CHRISTIAN) 15 March 2012 See paragraphs [0038]–[0042] and figures 1–3.	1–24



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

27 July 2017 (27.07.2017)

Date of mailing of the international search report

27 July 2017 (27.07.2017)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea



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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/059641

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015-0369023 A1	24/12/2015	CA 2900968 A1 MX 2015010395 A WO 2014-124533 A1	21/08/2014 22/02/2016 21/08/2014
US 2014-0083689 A1	27/03/2014	AU 2013-318458 A1 AU 2013-318458 B2 CA 2882582 A1 CN 104812992 A EP 2898179 A2 MX 2015003602 A US 9010442 B2 WO 2014-046841 A2 WO 2014-046841 A3	19/03/2015 11/08/2016 27/03/2014 29/07/2015 29/07/2015 05/06/2015 21/04/2015 27/03/2014 02/04/2015
US 2014-0262240 A1	18/09/2014	WO 2014-163853 A2 WO 2014-163853 A3	09/10/2014 02/04/2015
US 2014-0299330 A1	09/10/2014	AU 2013-377937 A1 AU 2013-377946 A1 CA 2897435 A1 CA 2897449 A1 EP 2929129 A1 EP 2929129 A4 EP 2929130 A1 EP 2929130 A4 US 2014-0262321 A1 WO 2014-123540 A1 WO 2014-123549 A1	18/06/2015 02/07/2015 14/08/2014 14/08/2014 14/10/2015 23/11/2016 14/10/2015 10/08/2016 18/09/2014 14/08/2014 14/08/2014
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