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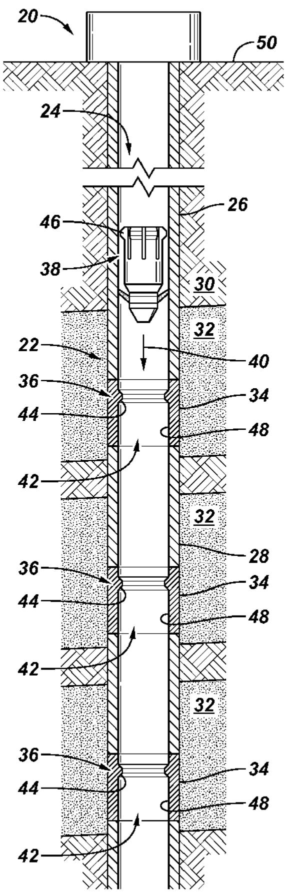
[Continued on next page]

(54) Title: COMPLETION METHOD FOR STIMULATION OF MULTIPLE INTERVALS



(57) Abstract: A technique provides for stimulating or otherwise treating multiple intervals/zones of a well by controlling flow of treatment fluid via a plurality of flow control devices. The flow control devices are provided with internal profiles and flow through passages. Hydraulic darts are designed for selective engagement with the internal profiles of specific flow control devices, and each hydraulic dart may be moved downhole for engagement with and activation of a specific flow control device

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COMPLETION METHOD FOR STIMULATION OF MULTIPLE INTERVALS

BACKGROUND

[0001] Hydrocarbon fluids are obtained from subterranean geologic formations, referred to as reservoirs, by drilling wells that penetrate the hydrocarbon-bearing formations. In some applications, a well is drilled through multiple well zones and each of those well zones may be treated to facilitate hydrocarbon fluid productivity. For example, a multizone vertical well or horizontal well may be completed and stimulated at multiple injection points along the well completion to enable commercial productivity. The treatment of multiple zones can be achieved by sequentially setting bridge plugs through multiple well interventions. In other applications, drop balls are used to open sliding sleeves at sequential well zones with size-graduated drop balls designed to engage seats of progressively increasing diameter.

SUMMARY

[0002] In general, the present disclosure provides a methodology and system for stimulating or otherwise treating multiple intervals/zones of a well by controlling flow of treatment fluid via a plurality of flow control devices. The flow control devices are provided with internal profiles and flow through passages. Hydraulic darts are designed for selective engagement with the internal profiles of specific flow control devices, and each dart may be moved downhole for engagement with and activation of a specific flow control device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Certain embodiments will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate only the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0004] Figure 1 is a schematic illustration of an example of a well system comprising a plurality of flow control devices that may be selectively actuated, according to an embodiment of the disclosure;

[0005] Figure 2 is a schematic illustration of flow control devices engaged by corresponding hydraulic darts, according to an embodiment of the disclosure;

[0006] Figure 3 is a cross-sectional illustration of an example of a flow control device, according to an embodiment of the disclosure;

[0007] Figure 4 is a graphical representation illustrating the time delay in pressure buildup used to actuate an embodiment of a hydraulic dart, according to an embodiment of the disclosure;

[0008] Figure 5 is a cross-sectional view of an example of a hydraulic dart, according to an embodiment of the disclosure;

[0009] Figure 6 is a cross-sectional view of the hydraulic dart illustrated in Figure 4 but in a different operational position, according to an embodiment of the disclosure;

[0010] Figure 7 is a cross-sectional view of the hydraulic dart illustrated in Figure 4 but in a different operational position, according to an embodiment of the disclosure;

[0011] Figure 8 is a cross-sectional view of an alternate embodiment of a hydraulic dart, according to an embodiment of the disclosure;

[0012] Figure 9 is a cross-sectional view of another alternate embodiment of a hydraulic dart, according to an embodiment of the disclosure;

[0013] Figure 10 is a cross-sectional view of the hydraulic dart illustrated in Figure 9 positioned adjacent an internal profile of a flow control device, according to an embodiment of the disclosure;

[0014] Figure 11 is a cross-sectional view of the hydraulic dart illustrated in Figure 9 but in a different operational position, according to an embodiment of the disclosure;

[0015] Figure 12 is a cross-sectional view of an alternate embodiment of the hydraulic dart, according to an embodiment of the disclosure;

[0016] Figure 13 is a cross-sectional view of the hydraulic dart illustrated in Figure 12 engaging an internal profile of a flow control device, according to an embodiment of the disclosure;

[0017] Figure 14 is a cross-sectional view of the hydraulic dart illustrated in Figure 12 but in a different operational position, according to an embodiment of the disclosure;

[0018] Figure 15 is a cross-sectional view of the hydraulic dart illustrated in Figure 12 but in a different operational position, according to an embodiment of the disclosure; and

[0019] Figure 16 is a cross-sectional view of an alternate embodiment of the hydraulic dart, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0020] In the following description, numerous details are set forth to provide an understanding of some illustrative embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0021] The disclosure herein generally relates to a system and methodology which facilitate multi-zonal completion and treatment of a well. For example, the methodology may comprise completing multizone vertical wells and/or horizontal wells that benefit from stimulation at multiple injection points along the wellbore to achieve commercial productivity. The individual well zones can be subjected to a variety of well treatments to facilitate production of desired hydrocarbon fluids, such as oil and/or gas. The well treatments may comprise stimulation treatments, such as fracturing treatments, performed at the individual well zones. However, a variety of other well treatments may be employed utilizing various types of treatment materials, including fracturing fluid, proppant materials, slurries, chemicals, and other treatment materials designed to enhance the productivity of the well. The present approach to multi-zonal completion and treatment reduces completion cycle times, increases or maintains completion efficiency, improves well productivity, and increases recoverable reserves.

[0022] Also, the well treatments may be performed in conjunction with many types of well equipment deployed downhole into the wellbore. For example, various completions may employ a variety of flow control devices which are used to control the lateral flow of fluid out of and/or into the completion at the various well zones. In some applications, the flow control devices are mounted along a well casing to control the flow of fluid between an interior and exterior of the well casing. However, flow control devices may be positioned along internal tubing or along other types of well strings/tubing structures deployed in the wellbore. The flow control devices may comprise sliding sleeves, valves, and other types of flow control devices which may be actuated by a member dropped down through the tubular structure.

[0023] Referring generally to Figure 1, an example of one type of application utilizing a plurality of flow control devices is illustrated. The example is provided to facilitate explanation, and it should be understood that a variety of well completion systems and other well or non-well related systems may utilize the methodology described herein. The flow control devices may be located at a variety of positions and in varying numbers along the tubular structure depending on the number of external zones to be treated.

[0024] In Figure 1, an embodiment of a well system 20 is illustrated as comprising downhole equipment 22, e.g. a well completion, deployed in a wellbore 24. The downhole equipment 22 may be part of a tubing string or tubular structure 26, such as well casing, although the tubular structure 26 also may comprise many other types of well strings, tubing and/or tubular devices. Additionally, downhole equipment 22 may include a variety of components, depending in part on the specific application, geological characteristics, and well type. In the example illustrated, the wellbore 24 is substantially vertical and tubular structure 26 comprises a casing 28. However, various well completions and other embodiments of downhole equipment 22 may be used in a well system having other types of wellbores, including deviated, e.g. horizontal, single bore, multilateral, cased, and uncased (open bore) wellbores.

[0025] In the example illustrated, wellbore 24 extends down through a subterranean formation 30 having a plurality of well zones 32. The downhole equipment 22 comprises a plurality of flow control devices 34 associated with the plurality of well zones 32. For example, an individual flow control device 34 may control flow from tubular structure 26 into the surrounding well zone 32 or vice versa. In some applications, a plurality of flow control devices 34 may be associated with each well zone 32. By way of example, the illustrated flow control devices 34 may comprise sliding sleeves, although other types of valves and devices may be employed to control the lateral fluid flow.

[0026] As illustrated, each flow control device 34 comprises a seat member 36 designed to engage a dart 38 which is dropped down through tubular structure 26 in the direction illustrated by arrow 40. Each dropped dart 38 may be hydraulically controlled to selectively engage a specific seat member 36 of a specific flow control device 34 to enable actuation of that specific flow control device 34. For example, the hydraulic control may be exercised via hydraulic pressure and/or flow rate acting against the dart 38 and controlled from a surface location. Engagement of the dart 38 with the specific, corresponding seat member 36 is not dependent on matching the diameter of the seat member 36 with a diameter of the dart 38. In the embodiment of Figure 1, for example, the plurality of flow control devices 34 and their corresponding seat members 36 may be formed with longitudinal flow through passages 42 having diameters which are of common size. This enables maintenance of a relatively large flow passage through the tubular structure 26 across the multiple well zones 32.

[0027] In the example illustrated, each seat member 36 comprises a profile 44, such as a lip, ring, unique surface feature, recess, or other profile which is designed to engage a corresponding engagement feature 46 of the dart 38. By way of example, the profile 44 may be formed in a sidewall 48 of seat member 36, the sidewall 48 also serving to create longitudinal flow through passage 42. In some applications, the engagement feature 46 is controlled by a hydraulically actuated mandrel which may be moved relative to a surrounding dart housing according to hydraulic input, e.g. hydraulic pressure and/or flow rate. The engagement feature 46 may be selectively actuated at a desired corresponding flow control device to prevent passage of the dart 38 and to enable shifting/actuation of that specific flow control device 34.

[0028] Referring generally to Figure 2, a schematic example of a system and methodology for treating multiple well zones is illustrated. In this example, each flow control device 34 is actuated by movement of the seat member 36 once suitably engaged by a corresponding dart 38. Each seat member 36 comprises profile 44 which can be engaged by actuating the engagement feature 46 of dart 38 after dart 38 is delivered downhole from a surface location 50 (see Figure 1). Because seating of the dart 38 is not dependent on decreasing seat diameters, a diameter 52 of each flow through passage 42 may be the same from one seat member 36 to the next. This enables construction of darts 38 having a common diameter 54 when in a radially contracted configuration during movement down through tubular structure 26 prior to actuation of the engagement feature 46 to a radially outward, locked position.

[0029] In one example of a multizone treatment operation, the darts 38 are selectively, hydraulically actuated in a manner enabling engagement of seat members 36 sequentially starting at the lowermost or most distal flow control device 34. The dart 38 initially dropped is pumped down through flow control devices 34 until the engagement feature 46 is actuated radially outwardly into engagement with the profile 44 of the lowermost seat member 36 illustrated in the example of Figure 2. Once the initial dart 38 is seated in the distal seat member 36 and the engagement feature 46 is locked, pressure is applied through the tubular structure 26 and against the dart 38 to transition the seat member 36 and the corresponding flow control device 34 to a desired operational configuration. For example, the flow control device 34 may comprise a sliding sleeve which is transitioned to an open flow position to enable outward flow of a fracturing treatment or other type of treatment into the surrounding well zone 32.

[0030] After the initial well zone is treated, a subsequent dart 38 is dropped down through the flow through passages 42 of the upper flow control device or devices 34 until the engagement feature 46 is actuated and locked outwardly into engagement with the next sequential profile 44 of the next sequential flow control device 34. Pressure may then again be applied down through the tubular structure 26 to transition the flow control device 34 to a desired operational configuration which enables application of a desired treatment of the surrounding well zone 32. A third dart 38 may then be dropped for actuation and engagement with the seat member 36 of the third flow control device 34 to enable actuation of the third flow control device and treatment of the surrounding well zone. This process may be repeated as desired for each additional flow control device 34 and well zone 32. Depending on the application, a relatively large number of darts 38 is easily deployed to enable actuation of specific flow control devices along the wellbore 24 for the efficient treatment of multiple well zones.

[0031] The methodology may be used in cemented or open-hole completion operations, and darts 38 are used as free fall and/or pump-down darts to selectively engage and operate sliding sleeves or other types of flow control devices 34. Additionally, the darts 38 may be designed to enable immediate flow back independent of chemical processes or milling to remove plugs. In open-hole applications, hydraulic set external packers or swellable packers may be used to isolate well zones along wellbore 24.

[0032] In one example of an application, the flow control devices 34 are sliding sleeve valves which are initially run-in-hole with the casing 28 to predetermined injection point depths for a fracture stimulation. A casing cementation operation is then performed utilizing, for example, standard materials and procedures. In open-hole applications, open-hole packers may be used instead of cementation. Prior to fracture stimulation, a pressure activated sliding sleeve valve set opposite the deepest injection point is opened or, alternatively, this interval can be perforated using a variety of perforating techniques. In other applications, the sliding sleeve valve at the deepest injection point may be opened via the initial dart 38.

[0033] After creating the desired opening or openings at the deepest injection point, fracture treatment fluid is pumped into this first interval. During a treatment flush, a dart 38 is pumped down and this initial dart is actuated to engage a specific sliding sleeve 34. In some applications, the first interval may not be fracture treated but instead used to allow pumping down the first dart 38. When the dart 38 engages, fluid is pumped to increase pressure until the sliding sleeve 34 shifts to an open position. At this stage, the fracture treatment fluid is pumped downhole and into the surrounding well zone 32. This process of launching darts 38 in the treatment flush is continued until all of the intervals/well zones 32 are treated. The well may be flowed back immediately or shut-in for later flow back. The darts 38 may later be removed via milling, dissolving, or through other suitable techniques to restore the unrestricted internal diameter of the casing.

[0034] The flow control devices 34 may comprise a variety of devices, including sliding sleeves. One example of a flow control device/sliding sleeve valve 34 is illustrated in Figure 3. In this embodiment, the sliding sleeve valve 34 comprises a ported housing 56 designed for running into the well with the casing 28. The housing 56 comprises at least one flow port 58 to enable radial or lateral flow through the housing 56 between an interior and an exterior of the housing. The housing 56 also may comprise end connections 60, e.g. casing connections, for coupling the housing 56 to the casing 38 or to another type of tubular structure 26.

[0035] In the embodiment illustrated, seat member 36 is in the form of a sliding sleeve 62 slidably positioned along an interior surface of the housing 56 between containment features 64. During movement downhole, the sliding sleeve 62 may be held in a position covering flow ports 58 by a retention member 66, such as a shear screw. The sliding sleeve 62 further comprises profile 44 designed to engage the engagement feature 46 of a dart 38 when the engagement feature 46 is in an actuated position. In some applications, the sliding sleeve 62 may comprise a secondary profile 68 designed to engage, for example, a suitable shifting tool. The secondary profile 68 provides an alternative way to open or close the sliding sleeve valve 34. When a designated dart 38 is engaged with profile 44 via engagement feature 46, application of pressure against the dart 38 causes retention member 66 to shear or otherwise release, thus allowing sliding sleeve 62 to transition along the interior of housing 56 until ports 58 are opened to lateral fluid flow. The seated dart 38 also isolates the casing volume below the sliding sleeve valve 34.

[0036] According to various environments described herein, the hydraulic darts 38 may be controlled from the surface using gross changes to flow or pressure. Both flow change and pressure change types of hydraulic darts 38 generally are designed so that a dart will temporarily seat against profile 44 and then pass through the flow control device 34 after a certain pressure is exceeded, e.g. after an applied pressure is sufficient to flex a collet carrying engagement feature 46. In one embodiment of pressure controlled hydraulic darts, a mandrel is moved relative to a collet in response to a pressure differential across the dart 38. A spring member is used to counter movement of the mandrel by pushing the mandrel in an uphole direction. The stiffness of the spring member is selected such that it will compress at a differential pressure (delta P) less than that required to push the engagement feature 46 past the internal profile 44. An orifice is used to regulate the flow of control fluid between two sides of a piston attached to the mandrel. Additionally, a check valve may be provided in parallel with the orifice to allow the mandrel to move back to its rest position at a quicker rate.

[0037] The orifice introduces a timing factor. For example, a certain amount of time is required for the mandrel to complete its motion and to lock the engagement feature 46 in place. If the pressure differential increases during the mandrel transition interval, the dart 38 is moved through the flow control device 34 and re-set. Additionally, a dart 38 that has been set by locking engagement feature 46 for interaction with profile 44 can be released by dropping the pressure below a spring pressure level and waiting a predetermined period of time to allow the mandrel to re-set. Once re-set, an increase in the pressure difference above the pressure differential needed to move the engagement feature 46 past the internal profile 44 allows the dart 38 to be pumped through that particular flow control device. In Figure 4, a graphical representation is provided to express the relationship between pressure and time used either to actuate the engagement feature 46 for engagement with profile 44 and actuation of the flow control device 34, e.g. a frac sleeve, or to enable the dart 38 to be pumped past the flow control device 34.

[0038] Referring generally to Figure 5, an example of hydraulic dart 38 is illustrated. In the illustrated embodiment, pressure differentials may be created from a surface location and used to actuate the dart 38 for retention at a specific flow control device 34 or to move the dart 38 past the flow control device 34. The hydraulic dart 38 may comprise a hydraulic actuation system 69 comprising a mandrel 70 slidably mounted within a surrounding dart housing 72. The mandrel 70 may have an open interior 74 which forms part of an overall dart flow through passage 76. The mandrel 70 may be sealingly engaged with the surrounding dart housing 72 via at least one mandrel seal 78.

Additionally, mandrel 70 is coupled to a locking member 80, such as a locking ring or shoulder, positioned to engage and lock the engagement feature 46 in a radially outward position when mandrel 70 is transitioned linearly to an actuated position. By way of example, engagement feature 46 may be mounted on a collet 82 coupled to or formed as part of dart housing 72.

[0039] Within open interior 74, a ball or other type of flow blocking member 84 is positioned to seat against an internal seat 86 within mandrel 70. The flow blocking member 84 and internal seat 86 cooperate to function as a check valve which allows pressure to be applied in a downhole direction while allowing flow back in an uphole direction. Pumping down fluid against dart 38 and member 84 tends to shift mandrel 70 with respect to the dart housing 72, as illustrated in Figure 6. However, this relative movement of mandrel 70 is resisted by a spring member 88 located, for example, between a shoulder 90 of mandrel 70 and a lead end 92 of dart 38.

[0040] The illustrated example of dart 38 further comprises an internal cavity 94 containing an internal fluid 96, e.g. hydraulic fluid, which passes through an orifice 98 as mandrel 70 is moved relative to dart housing 72. The orifice 98 controls locking of engagement feature 46 according to a predetermined pressure and time period. For example, pressure from above may be applied against dart 38 to create a pressure differential sufficient to overcome spring member 88 without pushing engagement feature 46 and collet 82 past the internal profile 44. While this pressure level is held, the mandrel 70 is transitioned relative to dart housing 72 until locking member 80 locks engagement feature 46 and collet 82 in the radially outward position against internal profile 44, as illustrated in Figure 7. In this locked position, the pressure differential can be increased to cause dart 38 to shift the flow control device 34/sliding sleeve 62 to a desired position.

[0041] If the pressure differential is sufficiently decreased, spring member 88 is able to shift mandrel 70 with respect to dart housing 72 back to its original re-set position. A check valve 100 may be employed to enable faster return of the mandrel 72 its original position by allowing a freer flow of the internal dart fluid 96 as the mandrel 70 transitions back through dart housing 72. In the embodiment illustrated, a compensator piston 102 also is positioned within internal cavity 94 and acts against internal fluid 96. The compensator piston 102 can move to allow the total volume of internal fluid 96, e.g. oil, in the dart 38 to change due to, for example, thermal expansion. In an alternate embodiment, the compensator piston 102 may be located above or on an opposite side of orifice 98, as illustrated in Figure 8. In this latter embodiment, the compensator piston 102 is positioned so it will not be moved by the pressure across the orifice 98 during cycling. In this example, the compensator piston 102 has an inside diameter which matches the outside diameter of the mandrel seal 78.

[0042] In the table below, various states of the mandrel 70 and the corresponding functions of dart 38 are set forth based on the pressure differential applied to the dart. In this example, the pressure differential may be lower or higher than the pressure differential required to compress spring member 88, to flex collet 82 (i.e. move engagement feature 46 past the internal profile 44), and/or to shear the shear member 66 of the flow control device 34 engaged by the dart 38. Various pressure differentials, mandrel states, and dart functions can be provided as follows:

Pressure differential is	Mandrel state	
Lower than spring, collet, and shear screws	Up/unlocked	Dart will stay in sleeve
Lower than spring, collet, and shear screws	Down/locked	Dart will stay in sleeve, mandrel will move up
Higher than spring, lower than collet, lower than shear screws	Up/unlocked	Dart will stay in sleeve, mandrel will move down
Higher than spring, lower than collet, lower than shear screws	Down/locked	Dart will stay in sleeve, mandrel will stay down
Higher than spring and collet, lower than shear screws	Up/unlocked	Dart will pass through
Higher than spring and collet, lower than shear screws	Down/locked	Dart will stay in sleeve, mandrel will stay down
Higher than spring, collet, and shear screws	Up/unlocked	Dart will pass through
Higher than spring, collet, and shear screws	Down/locked	Screws will shear and sleeve will open

[0043] Referring generally to Figures 9-11, an alternate embodiment of the hydraulic dart 38 is illustrated. In this embodiment, the compensator piston 102 has an outside diameter that matches the outside diameter of the mandrel seal 78. Additionally, the spring member 88 is located within internal cavity 94 containing internal fluid 96, e.g.

hydraulic oil. Otherwise, the functionality of the alternate hydraulic dart 38 is substantially similar to that described above with reference to the embodiments of Figures 4-8.

[0044] For example, the hydraulic dart 38 may be pumped down through the casing 38 or other tubular structure in and un-actuated configuration, as illustrated in Figure 9. When the engagement feature 46 contacts the internal profile 44 of a given flow control device 34, a rapid increase in pressure can be used to move the engagement feature past the internal profile 44, as illustrated in Figure 10. However, a maintained pressure differential sufficient to compress spring member 88 without forcing engagement feature 46 past the internal profile 44 allows shifting of mandrel 70 to actuate the hydraulic dart 38 by moving the locking member 80 into a position adjacent the engagement feature 46, as illustrated in Figure 11. This locks the engagement feature 46 in a radially outward position and prevents it from passing through the flow control device. In this configuration, increased pressure can be used to actuate/shift the flow control device 34.

[0045] Referring generally to Figures 12-15, another alternate embodiment of the hydraulic dart 38 is illustrated. In this embodiment, the hydraulic dart 38 is flow controlled instead of pressure controlled. As illustrated in Figure 12, the internal flow blocking member 84 is in the form of a velocity fuse 104 instead of a simple ball or similar flow blocking member. Below a predetermined rate of flow, the flow blocking member 84, e.g. velocity fuse 104, is held open by a spring 106. Once the predetermined flow rate is exceeded, the drag force on the velocity fuse 104 forces it to compress the spring 106. As the velocity fuse 104 moves close to the seat 86, the force on the velocity fuse 104 increases in a positive feedback cycle which causes rapid movement toward and against the seat 86.

[0046] The velocity fuse 104 remains against seat 86 as long as the pressure above the velocity fuse 104 is higher than below. If the pressure differential is reduced to a level which allows the spring 106 to push the velocity fuse off the corresponding seat

86, the flow blocking member 84 is again shifted to an open position. If the available flow is less than the predetermined flow rate, the flow blocking member 84/velocity fuse 104 remains open.

[0047] A pressure differential is produced by the fluid flowing through the velocity fuse 104. If this pressure differential times the area of the mandrel seal 78 exceeds the spring preload of spring member 88, the mandrel 70 is shifted and spring member 88 is compressed. This flow rate can be referred to as the spring flow rate. Similarly, there is a predetermined flow rate which creates a sufficient pressure differential so that engagement feature 46 can be moved past the internal profile 44, e.g. the collet 82 can collapse to allow passage of the engagement feature 46. This flow rate can be referred to as the collet flow rate.

[0048] In operation, the dart 38 is dropped or pumped down until the engagement feature 46 engages the internal profile 44 of a flow control device 34, as illustrated in Figure 13. If the flow rate is increased to the spring flow rate, spring member 88 is compressed and mandrel 70 is shifted until locking member 80 locks engagement feature 46 in the radially outward position, as illustrated in Figure 14. The flow rate may then be increased to close the velocity fuse 104 which enables application of pressure against the dart 38 to shift the flow control device 34 to a different operational position, as illustrated in Figure 15. Of course, if the flow rate is rapidly increased before the mandrel 70 is shifted, the pressure differential overcomes the collet 82 and moves the dart 38 past profile 44 and past the corresponding flow control device 34. Shifting of the mandrel 70 and actuation of the hydraulic dart 38 involves a time factor or time period to allow transition of mandrel 70 and locking of engagement feature 46, as described above and as illustrated in the graph of Figure 4.

[0049] In the table below, various states of the mandrel 70 and the velocity fuse 104 along with the corresponding functions of dart 38 are set forth based on the flow rate conditions applied to the dart. In this example, the flow rate may be lower or higher than required to compress spring member 88, to flex collet 82 (i.e. move engagement feature

46 past the internal profile 44), and/or to close the velocity fuse 104. Various flow rate conditions, mandrel states, velocity fuse states, and dart functions can be provided as follows:

Conditions	Mandrel state	Velocity Fuse	Results
Flow below spring, collet, and fuse rates	Up/unlocked	Open	Dart stay in the sleeve, mandrel stays up
Flow below spring, collet, and fuse rates	Down/locked	Open	Dart stays in the sleeve, mandrel moves up and unlocks
Flow above spring rate but below collet and fuse rates	Up/unlocked	Open	Dart stays in the sleeve, mandrel moves down and locks
Flow above spring rate but below collet and fuse rates	Down/locked	Open	Dart stays in the sleeve, mandrel stays down and locked
Flow above the spring and collet rates but below the fuse rate	Up/unlocked	Open	Dart passes through
Flow above the spring and collet rates but below the fuse rate	Down/locked	Open	Dart stays in the sleeve, mandrel stays down and locked
Flow above the spring, collet, and fuse rates	Up/unlocked	Open	Dart passes through, velocity fuse closes momentarily.
Flow above the spring, collet, and fuse rates	Down/locked	Open	Dart stays in the sleeve, mandrel stays down and locked, velocity fuse closes
Flow above the spring, collet, and fuse rates	Down/locked	Closed	Dart stays in the sleeve, mandrel stays down and locked, velocity fuse stays closed, frac sleeve opens

If the flow control dart 38 is set in the wrong flow control device/sliding sleeve 34, the dart 38 may be released by sufficiently lowering the flow rate to release the collet 82/engagement feature 46 from locking member 80.

[0050] In some applications, the hydraulic darts 38 may be modified to add a pressure relief valve in parallel with the orifice 98 to allow high flows/pressures to lock the dart 38 more quickly. Additionally, the darts 38 may be used with feedback systems to track the darts position at the surface. For example, each passage of the dart 38 through a corresponding internal profile 44 generates a pressure pulse that can be counted at the surface. Additionally, when dart 38 is set or locked in engagement with a corresponding internal profile 44, the dart can serve as a two-way reflector which can be pinged from the surface to verify position before committing to a final pressure increase to open or otherwise change the configuration of the flow control device.

[0051] Referring generally to Figure 16, another alternate dart configuration is illustrated. In this embodiment, each dart 38 is designed with electronics to count the number of times dart 38 passes through an internal profile 44 to facilitate actuation of the dart at the desired flow control device 34. In this example, the dart 38 comprises a sensor 108 which senses the change in internal pressure each time dart 38 encounters an internal profile 44 of a sliding sleeve 34 or other flow control device. The delay section pressure increases such that the electronic sensor 108 can detect the passage and electronics 110 can be used to count the number of sliding sleeves or other flow control devices 34 traversed by the dart 38. Just prior to engaging the specific, desired flow control device 34, electronics 110 activates a solenoid valve 112 which, in turn, opens a bypass 114 that serves to bypass the restrictor valve. This allows the locking member 82 to actuate the dart 38 by locking the collet 82/engagement feature 46, thus permitting actuation of the flow control device 34. Power may be supplied to electronics 110 and to solenoid valve 112 by a power source 116, such as a battery.

[0052] The system and methodology described herein may be employed in non-well related applications which require actuation of devices at specific zones along a tubular structure. Similarly, the system and methodology may be employed in many types of well treatment applications and other applications in which devices are actuated downhole via dropped darts without requiring any changes to the diameter of the internal fluid flow passage. Different well treatment operations may be performed at different well zones without requiring separate interventions operation. Sequential darts may simply be dropped into engagement with specific well devices for actuation of those specific well devices at predetermined locations along the well equipment positioned downhole.

[0053] Although only a few embodiments of the system and methodology have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

What is claimed is:

1. A method of treating a plurality of well zones (32), comprising:

providing each flow control device (34) of a plurality of flow control devices (34) with an internal profile (44) and a flow through passage (42);

locating the plurality of flow control devices (34) along a casing (38) in a wellbore (24); and

selecting a plurality of darts (38) constructed for engagement with the internal profile (44) of specific flow control devices (34) of the plurality of flow control devices (34);

releasing each dart (38) of the plurality of darts (38) for engagement with the internal profile (44) of the specific flow control device (34);

selectively actuating each dart (38) downhole to engage the internal profile (44) of the specific flow control device (34) by controlling the fluid acting on the dart (38) over a predetermined time period; and

creating a fluid barrier via engagement with the internal profile (44) for enabling a stimulation operation.

2. The method as recited in claim 1, wherein providing comprises providing a plurality of sliding sleeves (34).

3. The method as recited in claim 1, wherein providing comprises providing each flow through passage (42) of each flow control device (34) with the same diameter (52).

4. The method as recited in claim 1, wherein selecting comprises constructing each dart (38) of the plurality of darts (38) with a check valve (84, 86) oriented to allow fluid flow back through the flow through passage (42).

5. The method as recited in claim 1, wherein selectively actuating comprises controlling each dart (38) from the surface (50) via changes in pressure of the fluid acting against the dart (38).

6. The method as recited in claim 1, wherein selectively actuating comprises controlling each dart (38) from the surface (50) via changes in flow of the fluid acting against the dart (38).

7. The method as recited in claim 1, wherein selectively actuating comprises shifting a mandrel (70) within a housing (72) to lock an engagement feature (46) in a position for engagement with the internal profile (44) of a desired flow control device (34).

8. The method as recited in claim 7, wherein selectively actuating comprises controlling the rate of shifting of the mandrel (70) via using an orifice (98) to restrict flow of an internal fluid (96).

9. The method as recited in claim 8, further comprising resisting shifting of the mandrel (70) with a spring member (88).

10. The method as recited in claim 9, further comprising placing a check valve (100) in parallel with the orifice (98) to facilitate return of the mandrel (70) to an original rest position.

11. The method as recited in claim 7, further comprising providing an abrupt increase in pressure prior to the mandrel (70) locking the engagement feature (46) to enable movement of the dart (38) past the flow control device (34).

12. The method as recited in claim 7, further comprising providing an abrupt increase in flow rate prior to the mandrel (70) locking the engagement feature (46) to enable movement of the dart (38) past the flow control device (34).

13. The method as recited in claim 8, further comprising exposing the internal fluid (96) to a compensator piston (102).

14. A system (20) for use in treating a well, comprising:

a dart (38) having an engagement member (46) shaped to engage an internal profile (44) of a flow control device (34) located in a well completion (22) having a plurality of flow control devices (34), the dart (38) further comprising a mandrel (70) slidably mounted in a dart housing (72) such that shifting of the mandrel (70) is used to secure the engagement member (46) for sealing engagement with the internal profile (44) of a desired flow control device (34) to create a fluid barrier at the flow control device (34), the rate of shifting the mandrel (70) being controlled by restricting flow of an internal dart fluid (96).

15. The system as recited in claim 14, wherein the rate of shifting the mandrel (70) is controlled by an orifice (98).

16. The system as recited in claim 14, wherein the dart (38) further comprises a compensator piston (102) exposed to the internal dart fluid (96).

17. The system as recited in claim 14, wherein the dart (38) further comprises a flow through passage (76) extending through the mandrel (70) and a check valve (84, 86) for selectively blocking flow through the flow through passage (76).

18. A method, comprising:

deploying a multizone well stimulation system (20) into a wellbore (24) with a plurality of flow control devices (34);

providing each dart (38) of a plurality of darts (38) with a hydraulic actuation system (69) which is hydraulically manipulated via changes in flow rate or pressure acting on the dart (38) through the multizone well stimulation system (20);

releasing individual darts (38) into the multizone well stimulation system (20) for engagement with the predetermined flow control device (34); and

using the changes in flow rate or pressure to actuate the dart (38) into engagement with a predetermined flow control device (34) of the plurality of flow control devices (34), thus enabling actuation of the predetermined flow control device (34) to a different operational position.

19. The method as recited in claim 18, wherein providing comprises providing each dart (38) with a mandrel (70) which is selectively moved hydraulically through a dart housing (72) to lock an engagement feature (46) into an engagement position.

20. The method as recited in claim 19, wherein movement of the mandrel (70) is controlled by restricting flow of an internal dart fluid (96) via an orifice (98).

FIG. 1

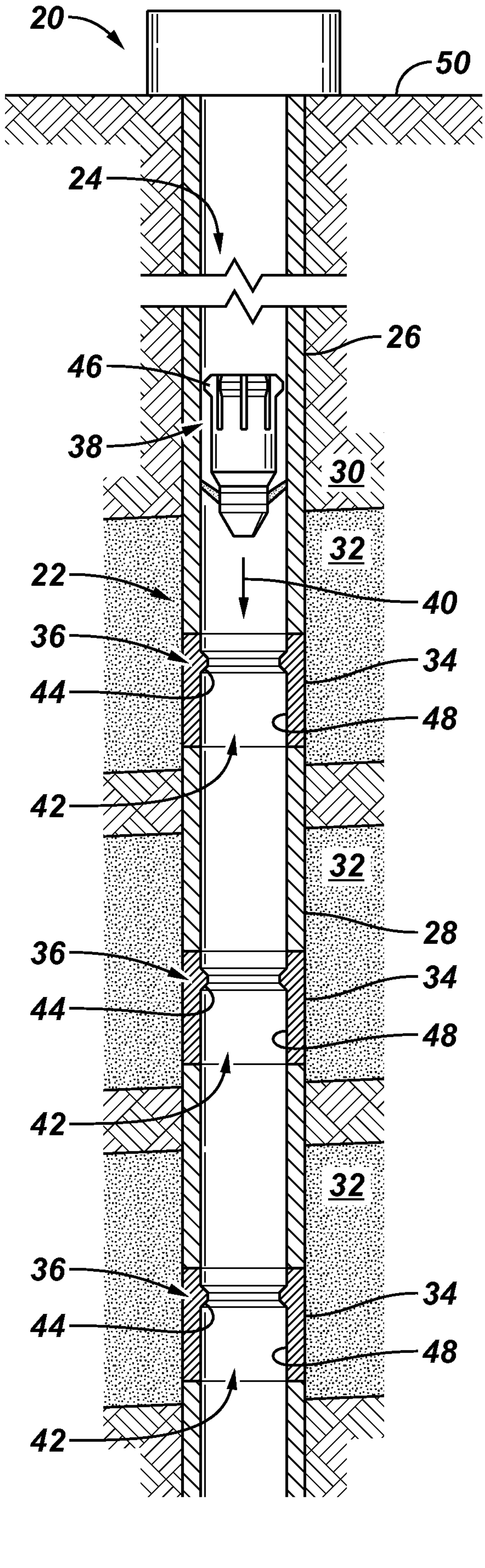
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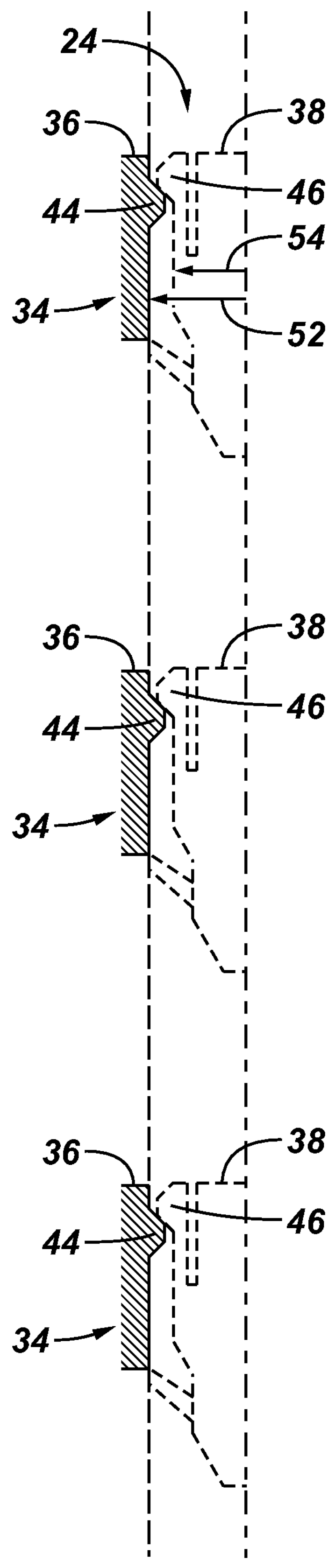
FIG. 2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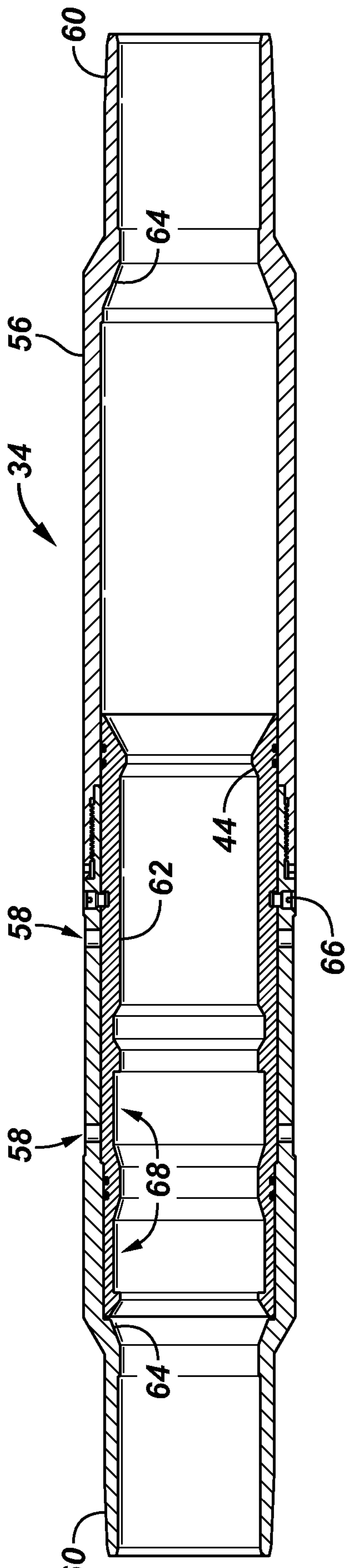
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FIG. 3

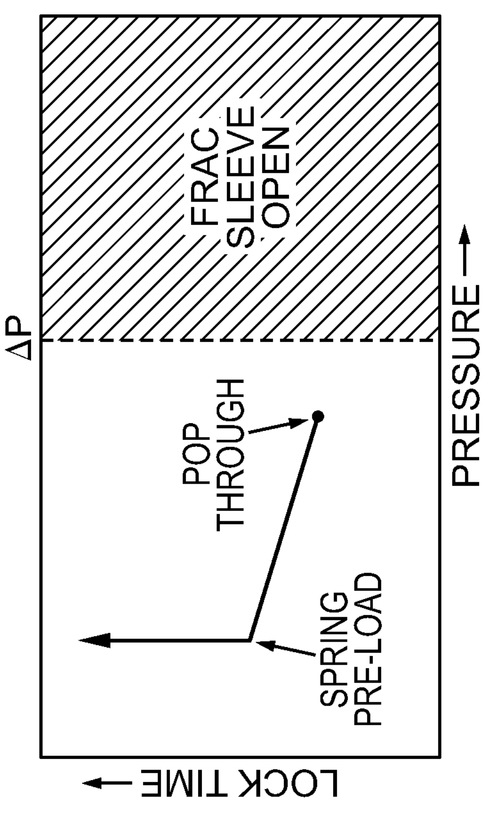
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FIG. 4

FIG. 5

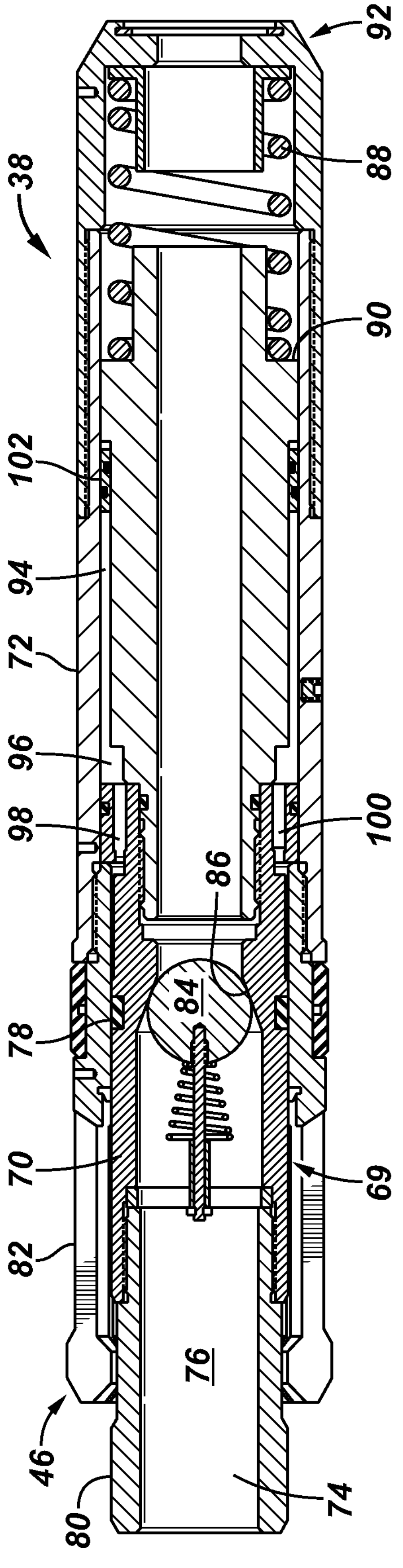
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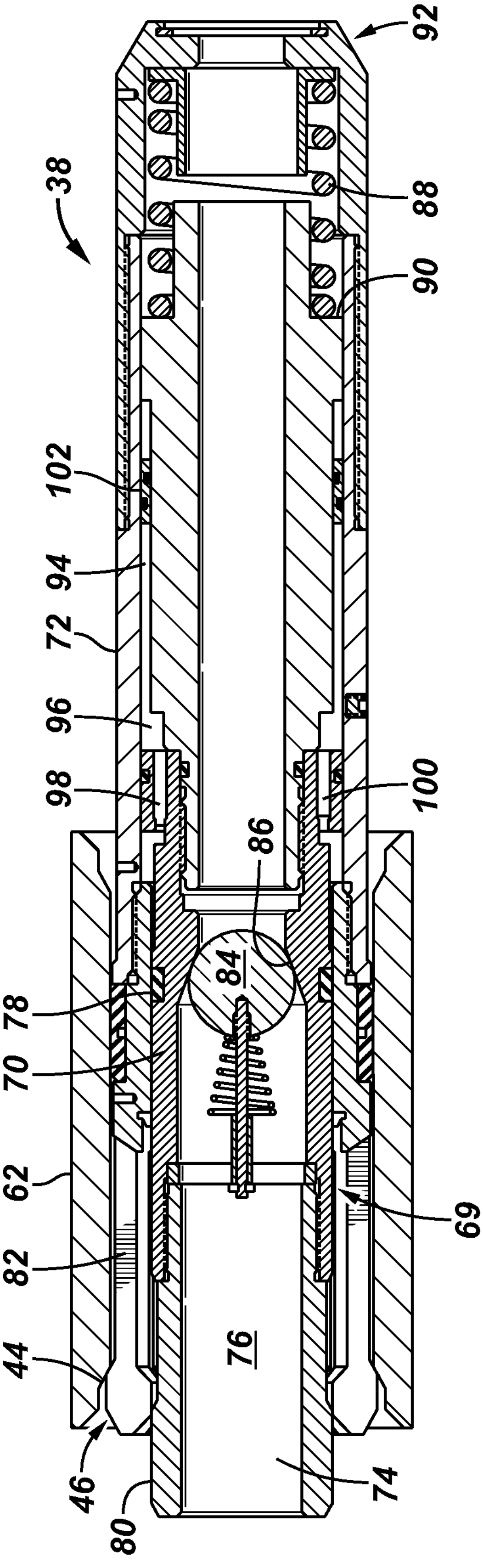
FIG. 6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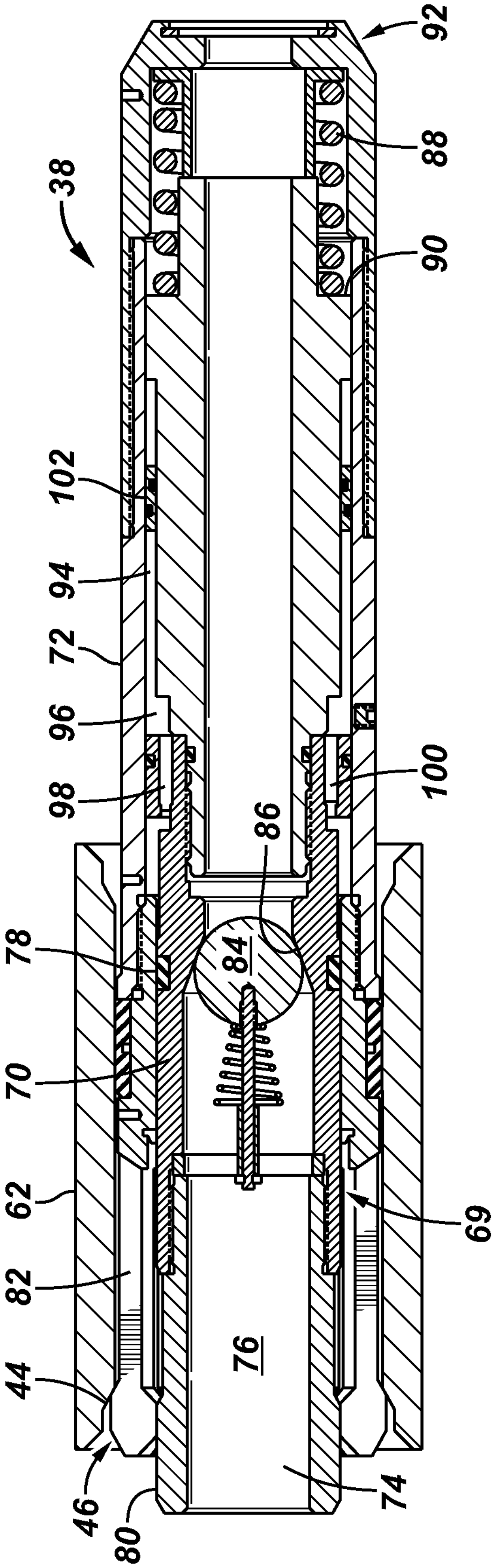
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FIG. 7

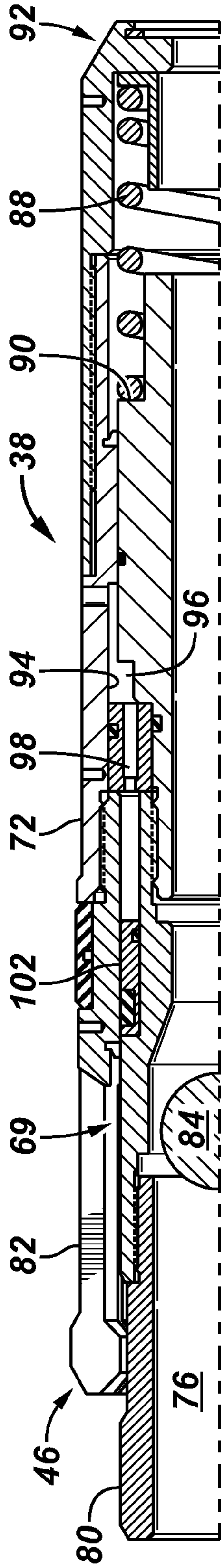
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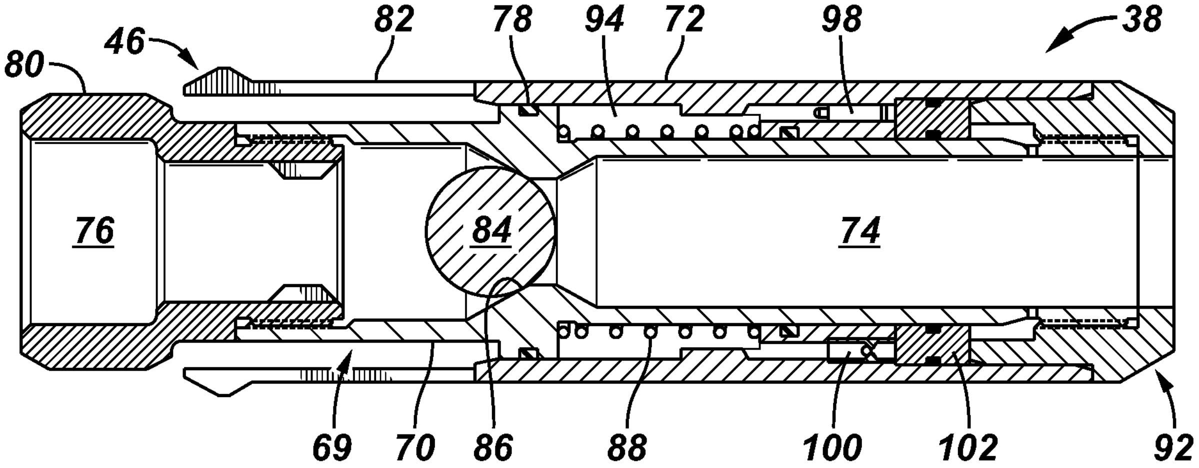
FIG. 8

FIG. 9



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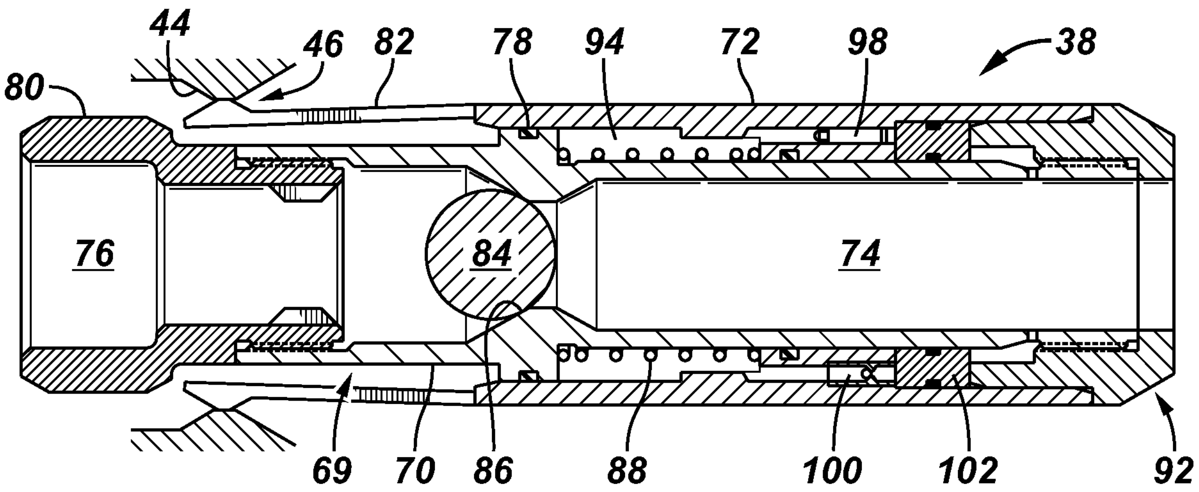
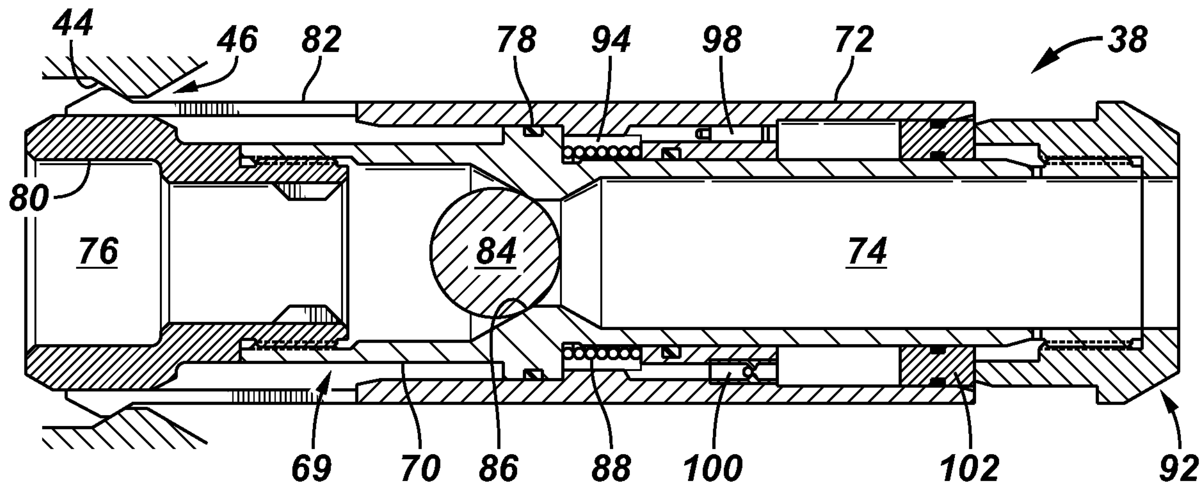


FIG. 11



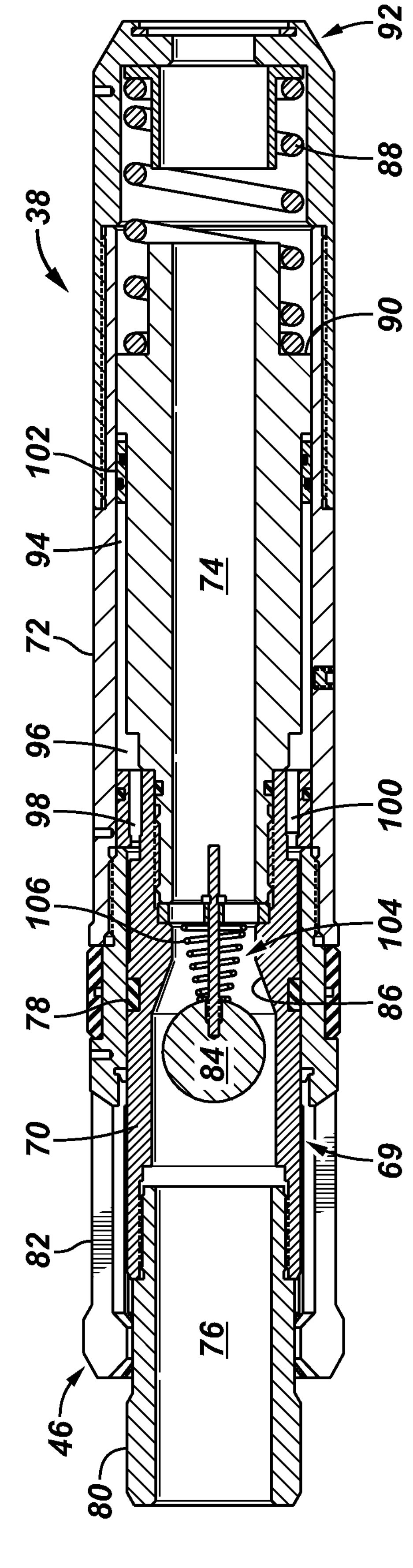

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FIG. 12

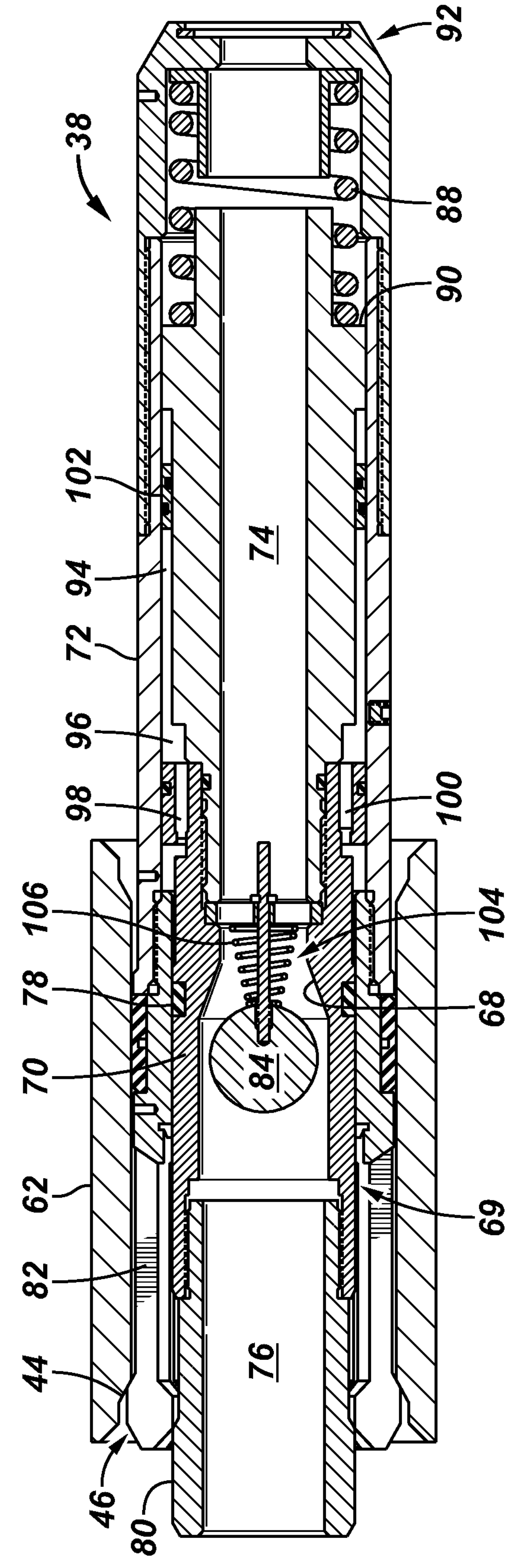
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FIG. 13

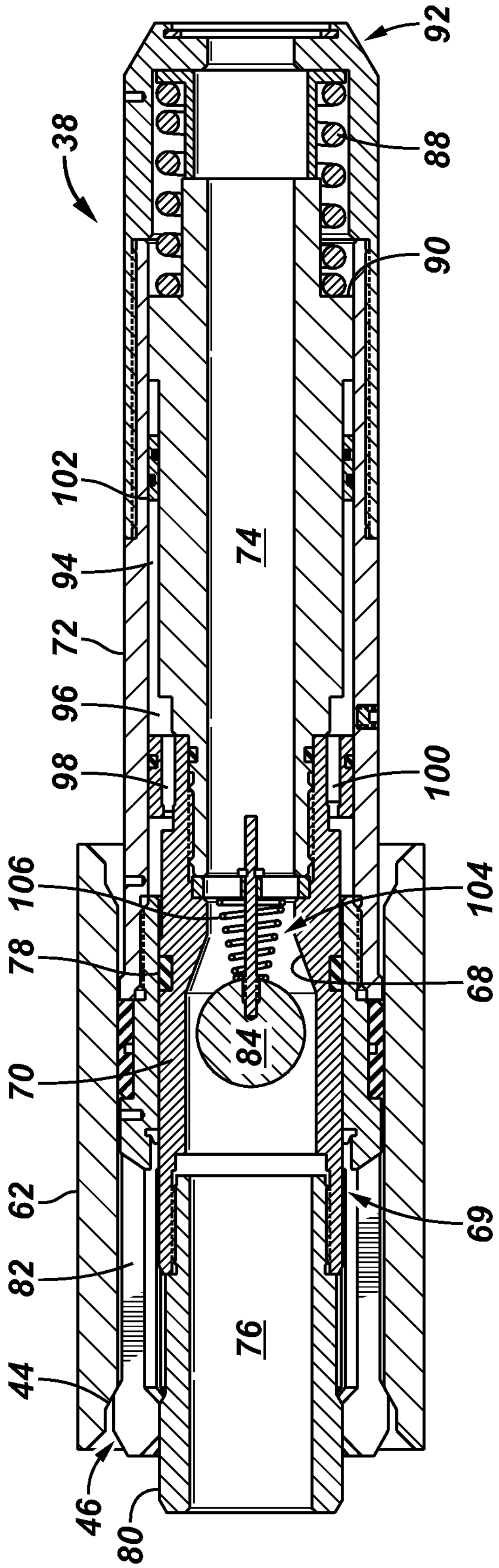
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FIG. 14

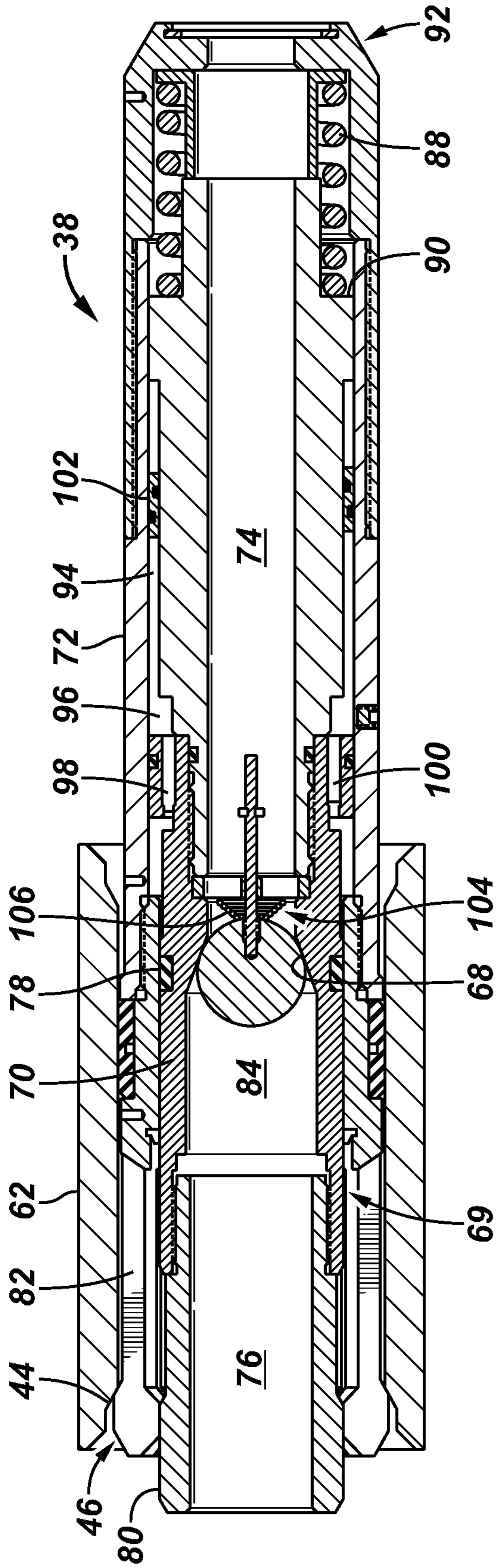
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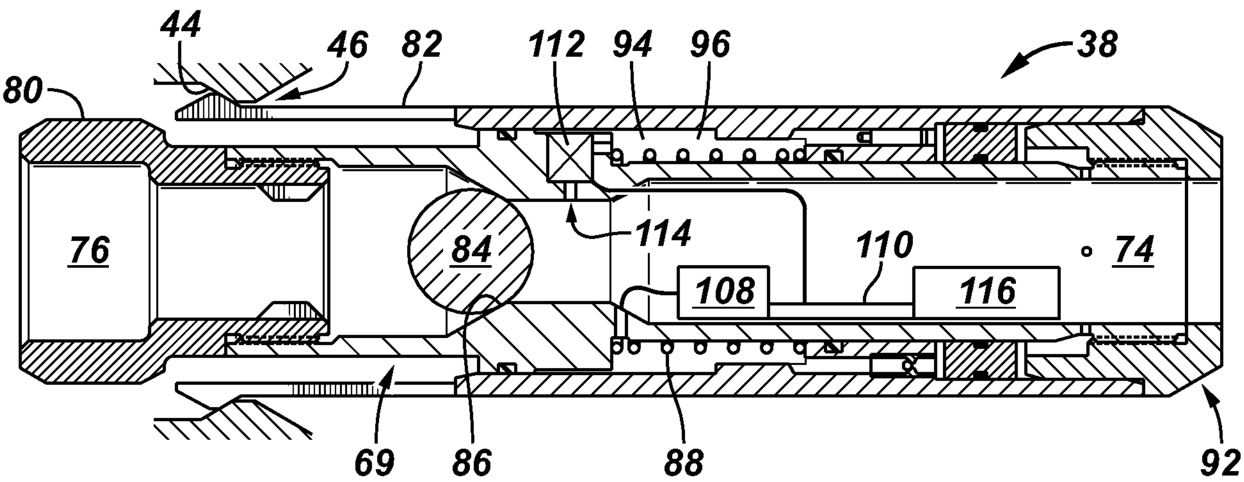
FIG. 15

FIG. 16



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/062098

A. CLASSIFICATION OF SUBJECT MATTER

E21B 34/08(2006.01)i, E21B 43/12(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 34/08; E21B 43/12

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: hydraulic, dart, engagement, flow, control, device, multiple, zone, activation and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010-059060 A1 (ZIEBEL AS) 27 May 2010 See abstract, page 3 line 7-page 4 line 31 and figures 2-5B.	1-20
A	EP 2372080 A2 (WEATHERFORD/LAMB, INC.) 05 October 2011 See abstract, paragraphs 45-64 and figures 2A-5C.	1-20
A	US 2007-0272411 A1 (LOPEZ DE CARDENAS, JORGE et al.) 29 November 2007 See abstract, paragraphs 30-32 and figures 3-4E.	1-20
A	US 2009-0260835 A1 (MALONE, BRADLEY P.) 22 October 2009 See abstract, paragraphs 2, 22-24 and figure 2.	1-20

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

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"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	Date of mailing of the international search report
28 FEBRUARY 2013 (28.02.2013)	**04 MARCH 2013 (04.03.2013)**

Name and mailing address of the ISA/KR
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. 82-42-472-7140

Authorized officer
LEE, Eun Ju
Telephone No. 82-42-481-5469

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2012/062098

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