METHOD AND APPARATUS FOR OPERATING A SHIFTING TOOL

The disclosure pertains to engaging a longitudinally slidable sleeve within a well. The apparatus comprises a tool string slidable beatable within said well and a shifting tool slidable beatable within said sleeve at an end of a tool string. The shifting tool has a central bore therethrough and keys operable to be extended therefrom. The apparatus further includes a reservoir in fluidic communication with said central bore of said shifting tool and being operable to contain and hold a quantity of a fluid at a predeter-mined pressure sufficient to actuate said shifting tool. The method comprises pressurizing the reservoir, reducing said pressure in said tool string above said reservoir slidably displacing said shifting tool and sleeve valve within said well by displacing said tool string therein.
METHOD AND APPARATUS FOR OPERATING A SHIFTING TOOL

BACKGROUND
[0001] The present application claims priority to U.S. Non-Provisional Application Serial No. 14/970,607, filed December 16, 2015, which is incorporated by reference.
[0002] The present disclosure relates to well completion in general and in particular to a method and apparatus for operating a high pressure shifting tool within a well.
[0003] Hydrocarbon fluids such as oil and natural gas are obtained from a subterranean geologic formation, referred to as a reservoir, by drilling a well that penetrates the hydrocarbon-bearing formation. Once a wellbore is drilled, various forms of well completion components may be installed in order to control and enhance the efficiency of producing the various fluids from the reservoir.
[0004] Fracturing is used to increase permeability of subterranean formations. A fracturing fluid is injected into the wellbore passing through the subterranean formation. A propping agent (proppant) is injected into the fracture to prevent fracture closing and, thereby, to provide improved extraction of extractive fluids, such as oil, gas or water.
[0005] The disclosure pertains to methods of treating an underground formation penetrated by either vertical wells or wells having a substantially horizontal section. Horizontal well in the present context may be interpreted as including a substantially horizontal portion, which may be cased or completed open hole, wherein the fracture is transversely or longitudinally oriented and thus generally vertical or sloped with respect to horizontal. The following disclosure will be described using horizontal well but the methodology is equally applicable to vertical wells.
[0006] The industry has privileged, when it comes to hydraulic fracturing, what is known as being "plug-and-perf" technique. Horizontal wells may extend hundreds of meters away from the vertical section of the wellbore. Most of the horizontal section of the well passes through the producing formation and are
completed in stages. The wellbore begins to deviate from vertical at the kickoff point, the beginning of the horizontal section is the heel and the farthest extremity of the well is the toe. Engineers perform the first perforating operation at the toe, followed by a fracturing treatment. Engineers then place a plug in the well that hydraulically isolates the newly fractured rock from the rest of the well. A section adjacent to the plug undergoes perforation, followed by another fracturing treatment. This sequence is repeated many times until the horizontal section is stimulated from the toe back to the heel. Finally, a milling operation removes the plugs from the well and production commences.

[0007] The common practice in the art is to perforate 4-6 clusters, and push a slickwater laden fluid at or above fracture pressure to create fractures; it is estimated that 30 to 60% of these perforations do not produce due to for example screen out, geological constraint, etc., and thus for every 100 perforations in a wellbore, commonly only 30 to 70 of the conventional perforations are useful for production.

[0008] To respond to that, some operations now involve what is known as pin-point fracturing, which may be defined as the operation of pumping a fluid above the fracturing pressure of the formation to be treated through a single entry. The entry may be a perforation, a valve, a sleeve, or a sliding sleeve. Generally, sliding sleeves in the closed position are fitted to the production liner. The production liner is placed in a hydrocarbon formation. An object is introduced into the wellbore from surface, and the object is transported to the target zone by the flow field or mechanically, for example using a wireline or a coiled tubing. When at the target location, the object is caught by the sliding sleeve and shifts the sleeve to the open position. A sealing device, such as a packer or cups, is positioned below the sleeve to be treated in order to isolate the lower portion of the wellbore. The sealing device is set, fluid is pumped into the fracture and then the sealing device is unset and moved below the next zone (or sleeve) to be treated. Representative examples of sleeve-based systems are disclosed in US 7,387,165, US 7,322,417, US 7,377,321, US 2007/01 07908, US 2007/0044958, US 201 0/0209288, US 7,387,165, US2009/0084553, US

[0009] One difficulty experienced in the actuation of sleeve valves within an oil well is that the shifting tool required to open and close the sleeve relies upon a pressure being maintained within commonly used shifting tools. In particular, when such shifting tools are utilized with long tool strings, it may be difficult to provide sufficient pressure to activate such shifting tool due to the pressure losses associated with such long tool strings. Additionally, it is also undesirable to move the tool string in such a pressurized state as such pressurized states are known to cause increased stress and wear on the pipe reducing the lifespan of such components. Improvements in actuating such tools would be welcome by the industry.

SUMMARY

[0010] In embodiments the disclosure pertains to methods for actuating a sleeve valve without requiring the tool string to remain in a pressurized state.

[0011] According to embodiments there is disclosed an apparatus for selectably engaging a longitudinally slidable sleeve within a well comprising a tool string slidably locatable within the well and a shifting tool slidably beatable within the sleeve at an end of a tool string. The shifting tool has a central bore therethrough and keys operable to be extended from an outer surface of the shifting tool when the central bore is supplied with the fluid above a predetermined pressure. The keys are engagable upon the sleeve so as to permit the shifting tool to move the sleeve longitudinally within the tubular body. The apparatus further comprises a reservoir in fluidic communication with the central bore of the shifting tool and being operable to contain and hold a quantity of a fluid at a predetermined pressure sufficient to actuate the shifting tool.
The apparatus may further include an isolation body adapted to retain the fluid in the reservoir after the pressure has been reduced in the tool string. The isolation body may comprise a check valve adapted to permit a flow of fluid into the reservoir in a downward direction only. The check valve may be located above the shifting tool.

The reservoir may be formed between an inner mandrel and an outer housing of the tool string. The inner mandrel and outer housing may be longitudinally movable relative to each other along the tool string. The outer housing may be operably connected to the tool and wherein the inner mandrel is operably connected to a pipe extending to a ground level of the well. The reservoir may be formed between an end wall and a lead protrusion extending radially outward from the inner mandrel. The end wall may slidably seal against the outer housing.

The outer housing may include a bypass protrusion extending radially inwardly therefrom at a position adapted to seal against the lead protrusion of the inner mandrel when the inner mandrel and outer housing are at a first position relative to each other. The bypass protrusion may be adapted to longitudinally disengage from the lead protrusion as the inner mandrel is slidably displaced relative to the outer housing so as to compress the reservoir. The bypass protrusion may include a bleed passage therethrough sized to permit a predetermined flow rate of fluid therethrough.

According to further embodiments there is disclosed a method for selectably engaging a longitudinally slideable sleeve within a well comprising providing a tool string slidably beatable within the well and providing a shifting tool slidably beatable within the sleeve at an end of a tool string. The shifting tool has a central bore therethrough and keys operable to be extended from an outer surface of the shifting tool when the central bore is supplied with the fluid above a predetermined pressure. The keys are engagable upon the sleeve so as to permit the shifting tool to move the sleeve longitudinally within the tubular body. The method further comprises providing a reservoir in fluidic communication with the central bore of the shifting tool and being operable to
contain and hold a quantity of a fluid at a predetermined pressure sufficient to actuate the shifting tool.

[0016] According to further embodiments there is disclosed a method for selectably engaging a longitudinally slidable sleeve within a well comprising locating a tool string having a shifting tool therein within the well, wherein the shifting tool has a central bore therethrough and keys operable to be extended from an outer surface of the shifting tool when the central bore is supplied with the fluid above a predetermined pressure, the keys being engagable upon the sleeve so as to permit the shifting tool to move the sleeve longitudinally within the tubular body. The method further comprises pressurizing a reservoir in fluidic communication with the central bore of the shifting tool and being operable to contain and hold a quantity of a fluid at a predetermined pressure sufficient to actuate the shifting tool to extend the keys from the outer surface of the shifting tool into engagement with a sleeve valve. The method further comprises reducing the pressure in the tool string above the reservoir and slidably displacing the shifting tool and sleeve valve within the well by displacing the tool string therein.

[0017] Other aspects and features of the present disclosure will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments in conjunction with the accompanying figures.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0018] Certain embodiments of the disclosure 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 drawings illustrate only the various implementations described herein and are not meant to limit the scope of various technologies described herein. The drawings show and describe various embodiments of the current disclosure.
FIG. 1 is a cross-sectional view of a wellbore having a plurality of flow control valves according to a first embodiment of the present disclosure located therealong.

FIG. 2 is a cross-sectional view of a control valves of for use in the system of FIG 1.

FIG. 3 is a longitudinal cross-sectional view of the control valve of FIG. 2 as taken along the line 3-3.

FIG. 4 is a detailed cross-sectional view of the extendable ports of the valve of FIG. 2 in a first or retracted position.

FIG. 5 is a detailed cross-sectional view of the extendable ports of the valve of FIG. 2 in a second or extended position with the sleeve valve in an open position.

FIG. 6 is a cross-sectional view of the valve of FIG. 2 as taken along the line 3-3 showing a shifting tool located therein.

FIG. 7 is an axial cross-sectional view of the shifting tool of FIG. 6 as taken along the line 7-7.

FIG. 8 a lengthwise cross sectional view of the shifting tool of FIG. 6 taken along the line 8-8 in FIG. 7 with a control valve located therein according to one embodiment with the sleeve engaging members located at a first or retracted position.

FIG. 9 is a cross-sectional view of the shifting tool of FIG. 6 taken along the line 8-8 with a control valve located therein according to one embodiment with the sleeve engaging members located at a second or extended position.

FIG. 10 is a perspective view of a shifting tool according to a further embodiment.

FIG. 11 is a side view of a well at a first step of engaging a sleeve valve according to the present method.

FIG. 12 is a side view of a well at a second step of opening a sleeve valve according to the present method.
FIG. 13 is a cross sectional view of a sleeve valve of an optional design having a reservoir formed inside according to the present disclosure at a first or initial position.

FIG. 14 is a detailed cross sectional view of a portion of a sleeve valve of Figure 13 at a second or pressurized position.

FIG. 15 is a detailed cross sectional view of a portion of a sleeve valve of Figure 13 at a second or pressurized position.

DETAILED DESCRIPTION

At the outset, it should be noted that in the development of any such actual embodiment, numerous implementation—specific decisions must be made to achieve the developer's specific goals, such as compliance with system related and business related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time consuming but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure. In addition, the composition used/disclosed herein can also comprise some components other than those cited. In the summary and this detailed description, each numerical value should be read once as modified by the term "about" (unless already expressly so modified), and then read again as not so modified unless otherwise indicated in context. Also, in the summary and this detailed description, it should be understood that a concentration range listed or described as being useful, suitable, or the like, is intended that any and every concentration within the range, including the end points, is to be considered as having been stated. For example, "a range of from 1 to 10" is to be read as indicating each and every possible number along the continuum between about 1 and about 10. Thus, even if specific data points within the range, or even no data points within the range, are explicitly identified or refer to only a few specific, it is to be understood that inventors appreciate and understand that any and all data points within the range are to be considered to have been specified, and
that inventors possessed knowledge of the entire range and all points within the range.

[0035] The statements made herein merely provide information related to the present disclosure and may not constitute prior art, and may describe some embodiments illustrating the disclosure.

[0036] In the specification and appended claims: the terms "connect", "connection", "connected", "in connection with", and "connecting" are used to mean "in direct connection with" or "in connection with via one or more elements"; and the term "set" is used to mean "one element" or "more than one element". Further, the terms "couple", "coupling", "coupled", "coupled together", and "coupled with" are used to mean "directly coupled together" or "coupled together via one or more elements". As used herein, the terms "up" and "down", "upper" and "lower", "upwardly" and downwardly", "upstream" and "downstream"; "above" and "below"; and other like terms indicating relative positions above or below a given point or element are used in this description to more clearly describe some embodiments of the disclosure.

[0037] Embodiments herein relate to methods of completing an underground formation using multi-stage pin-point fracturing for treating a well without using any sealing element.

[0038] Referring to FIG. 1, a wellbore 10 is drilled into the ground 8 to a production zone 6 by known methods. The production zone 6 may contain a horizontally extending hydrocarbon bearing rock formation or may span a plurality of hydrocarbon bearing rock formations such that the wellbore 10 has a path designed to cross or intersect each formation. As illustrated in FIG. 1, the wellbore includes a vertical section 12 having a valve assembly or Christmas tree 14 at a top end thereof and a bottom or production section 16 which may be horizontal or angularly oriented relative to the horizontal located within the production zone 6. After the wellbore 10 is drilled the production tubing 20 is of the hydrocarbon well is formed of a plurality of alternating liner or casing 22 sections and in line valve bodies 24 surrounded by a layer of cement 23 between the casing and the wellbore. The valve bodies 24 are adapted to control fluid flow
from the surrounding formation proximate to that valve body and may be located at predetermined locations to correspond to a desired production zone within the wellbore. In operation, between 8 and 100 valve bodies may be utilized within a wellbore although it will be appreciated that other quantities may be useful as well.

[0039] Turning now to FIG. 2, a perspective view of one valve body 24 is illustrated. The valve body 24 comprises a substantially elongate cylindrical outer casing 26 extending between first and second ends 28 and 30, respectively and having a central passage 32 therethrough. The first end 28 of the valve body is connected to adjacent liner or casing section 22 with an internal threading in the first end 28. The second end 30 of the valve body is connected to an adjacent casing section with external threading around the second end 30. The valve body 24 further includes a central portion 34 having a plurality of raised sections 36 extending axially therealong with passages 37 therebetween. As illustrated in the accompanying figures, the valve body 24 has three raised sections although it will be appreciated that a different number may also be utilized.

[0040] Each raised section 36 includes a radially movable body or port body 38 therein having an aperture 40 extending therethrough. The aperture 40 extends from the exterior to the interior of the valve body and is adapted to provide a fluid passage between the interior of the bottom section 16 and the wellbore 10 as will be further described below. The aperture 40 may be filled with a sealing body (not shown) when installed within a bottom section 16. The sealing body serves to assist in sealing the aperture until the formation is to be fractured and therefore will have sufficient strength to remain within the aperture until that time and will also be sufficiently frangible so as to be fractured and removed from the aperture during the fracturing process. Additionally, the port bodies 38 are radially extendable from the valve body so as to engage an outer surface thereof against the wellbore 10 so as to center the valve body 24 and thereby the production section within the wellbore.
[0041] Turning now to FIG. 3, a cross sectional view of the valve body 24 is illustrated. The central passage 32 of the valve body includes a central portion 42 corresponding to the location of the port bodies 38. The central portion is substantially cylindrical and contains a sliding sleeve 44 therein. The central portion 42 is defined between first or entrance and second or exit raised portions or annular shoulders, 46 and 48, respectively. The sliding sleeve 44 is longitudinally displaceable within the central portion 42 to either be adjacent to the first or second shoulder 46 or 48. At a location adjacent to the second shoulder, the sliding sleeve 44 sealably covers the apertures 40 so as to isolate the interior from the exterior of the bottom section 16 from each other, whereas when the sliding sleeve 44 is adjacent to the first shoulder 46, the sliding sleeve 44

[0042] The central portion 42 includes a first annular groove 50 a therein proximate to the first shoulder 46. The sliding sleeve 44 includes a radially disposed snap ring 52 therein corresponding to the groove 50 a so as to engage therewith and retain the sliding sleeve 44 proximate to the first shoulder 46 which is an open position for the valve body 24. The central portion 42 also includes a second annular groove 50 b therein proximate to the aperture 40 having a similar profile to the first annular groove 50 a. The snap ring 52 of the sleeve is receivable in either the first or second annular groove 50 a or 50 b such that the sleeve is held in either an open position as illustrated in FIG. 5 or a closed position as illustrated in FIG. 4. The sliding sleeve 44 also includes annular wiper seals 54 which will be described more fully below proximate to either end thereof to maintain a fluid tight seal between the sliding sleeve and the interior of the central portion 42.

[0043] The port bodies 38 are slidably received within the valve body 24 so as to be radially extendable therefrom. As illustrated in FIG. 3, the port bodies are located in their retracted position such that an exterior surface 60 of the port bodies is aligned with an exterior surface 62 of the raised sections 36. Each raised section may also include limit plates 64 located to each side of the port
bodies 38 which overlap a portion of and retain pistons within the cylinders as are more fully described below.

Each raised section 36 includes at least one void region or cylinder 66 disposed radially therein. Each cylinder 66 includes a piston 68 therein which is operably connected to a corresponding port body 38 forming an actuator for selectably moving the port bodies 38. Turning now to FIGS. 4 and 5, detailed views of one port body 38 are illustrated at a retracted and extended position, respectively. Each port body 38 may have an opposed pair of pistons 68 associated therewith arranged to opposed longitudinal sides of the valve body 24. It will be appreciated that other quantities of pistons 68 may also be utilized for each port body 38 as well. The pistons 68 are connected to the valve body by a top plate 70 having an exterior surface 72. The exterior surface 72 is positioned to correspond to the exterior surface 62 of the raised sections 36 so as to present a substantially continuous surface therewith when the port bodies 38 are in their retracted positions. The exterior surface 72 also includes angled end portions 74 so as to provide a ramp or inclined surface at each end of the port body 38 when the port bodies 38 are in an extended position. This will assist in enabling the valve body to be longitudinally displaced within a wellbore 10 with the vertical section 12 under thermal expansion of the production string and thereby to minimize any shear stresses on the port body 38.

The pistons 68 are radially moveable within the cylinders relative to a central axis of the valve body so as to be radially extendable therefrom. In the extended position illustrated in FIG. 5, the exterior surface 72 of the port bodies are adapted to be in contact with the wellbore 10 so as to extend the port body 38 and thereby enable the wellbore 10 to be placed in fluidic communication with the central portion 42 of the valve body 24. The pistons 68 may have a travel distance between their retracted positions and their extended positions of between 0.1 0 and 0.50 inches although it will be appreciated that other distances may also be possible. In the extended position, it will be possible to frac that location without having to also fracture the concrete which will be located between the valve body 24 and the wellbore wall thereby reducing the required
frac pressure. Additionally, more than one port body 38 may be utilized and radially arranged around the valve body so as to centre the valve body within the wellbore when the port bodies are extended therefrom.

[0046] The pistons 68 may include seals 76 therearound so as to seal the piston within the cylinders 66. Additionally, the port body 38 may include a port sleeve 78 extending radially inward through a corresponding port bore 81 within the valve body. A seal 80 may be located between the port sleeve 78 and the port bore 81 so as to provide a fluid tight seal therebetween. A snap ring 82 may be provided within the port bore 81 adapted to bear radially inwardly upon the port sleeve 78. In the extended position, the snap ring 82 compresses radially inwardly to provide a shoulder upon which the port sleeve 78 may rest so as to prevent retraction of the port body 38 as illustrated in FIG. 5. The pistons 68 may be displaceable within the cylinders 66 by the introduction of a pressurized fluid into a bottom portion thereof. It will also be appreciated that other sleeve valves may be utilized which do not include extendable pistons as illustrated herein as are commonly known in the art.

[0047] With reference to FIG. 3, the entrance bore 94 intersect the central passage 32 of the valve body 24. As illustrated each entrance bore 94 may be covered by a knock-out plug 102 so as to seal the entrance bore until removed. In operation, as concrete is pumped down the bottom section 16, it will be followed by a plug so as to provide an end to the volume of concrete. The plug is pressurized by a pumping fluid (such as water, by way of non-limiting example) so as to force the concrete down the production string and thereafter to be extruded into the annulus between the horizontal section and the wellbore. The knock-out plugs 102 are designed so as to be removed or knocked-out of the entrance bore by the concrete plug passing thereby. In such a way, once the concrete has passed the valve body 24, the concrete plug removes the knock-out plugs 102 so as to pressurize the entrance bore 94 and fluid bore 90 and thereafter to extend the pistons 68 from the valve body 24 once the pressurizing fluid has reached a sufficient pressure.
[0048] Turning now to FIG. 6, a shifting tool 200 is illustrated within the central passage 32 of the valve body 24. The shifting tool 200 is adapted to engage the sliding sleeve 44 and shift it between a closed position as illustrated in FIG. 4 and an open position in which the apertures 40 are uncovered by the sliding sleeve 44 so as to permit fluid flow between and interior and an exterior of the valve body 24 as illustrated in FIG. 5. The shifting tool 200 comprises a substantially cylindrical elongate tubular body 202 extending between first and second ends 204 and 206, respectively. The shifting tool 200 includes a central bore 210 therethrough (shown in FIGS. 7 through 9) to receive an actuator or to permit the passage of fluids and other tools therethrough. The shifting tool 200 includes at least one sleeve engaging member 208 radially extendable from the tubular body 202 so as to be selectively engageable with the sliding sleeve 44 of the valve body 24. As illustrated in the accompanying figures, three sleeve engaging members 208 are illustrated although it will be appreciated that other quantities may be useful as well.

[0049] The sleeve engaging members 208 comprise elongate members extending substantially parallel to a central axis 209 of the shifting tool between first and second ends 212 and 214, respectively. The first and second ends 212 and 214 include first and second catches 216 and 218, respectively for surrounding the sliding sleeve and engaging a corresponding first or second end 43 or 45, respectively of the sliding sleeve 44 depending upon which direction the shifting tool 200 is displaced within the valve body 24. As illustrated in FIGS. 8 and 9, the first and second catches 216 and 218 of the sleeve engaging member 208 each include and inclined surface 220 and 222, respectively facing in opposed directions from each other. The inclined surfaces 220 and 222 are adapted to engage upon either the first or second annular shoulder 46 or 48 of the valve body as the shifting tool 200 is pulled or pushed there into. The first or second annular shoulders 46 or 48 press the first or second inclined surface 220 or 222 radially inwardly so as to press the sleeve engaging members 208 inwardly and thereby to disengage the sleeve engaging members 208 from the sliding sleeve 44 when the sliding sleeve 44 has been shifted to a desired
position proximate to one of the annular shoulders. In an optional embodiment, one or both of the catches 216 or 218 may have an extended length as illustrated in FIG. 10 such that the sleeve engaging members are disengaged from the sliding sleeve at a position spaced apart from one of the first or second annular shoulders 46 or 48 and thereby adapted to position the sliding sleeve at a third or central position within the valve body 24.

[0050] Turning to FIG. 7, the sleeve engaging members are maintained parallel to the tubular body 202 of the shifting tool 200 by a parallel shaft 230. Each parallel shaft 230 is linked to a sleeve engaging member 208 by a pair of spaced apart linking arms 232. The parallel shaft 230 is rotatably supported within the shifting tool tubular body 202 by bearings or the like. The linking arms 232 are fixedly attached to the parallel shaft 230 at a proximate end and are received within a blind bore 234 of the sleeve engaging members 208. As illustrated in FIG. 6, the linking arms 232 are longitudinally spaced apart from each other along the parallel shaft 230 and the sleeve engaging member 208 so as to be proximate to the first and second ends 212 and 214 of the sleeve engaging member 208.

[0051] Turning now to FIG. 8, the tubular body 202 of the shifting tool includes a shifting bore 226 therein at a location corresponding to each sleeve engaging member. The shifting bore 226 extends from a cavity receiving the sleeve engaging member to the central bore 210 of the shifting tool 200. Each sleeve engaging member 208 includes a piston 224 extending radially therefrom which is received within the shifting bore 226. In operation, a fluid pressure applied to the central bore 210 of the shifting tool will be applied to the piston 224 so as to extend the piston within the shifting bore 226 and thereby to extend the sleeve engaging members 208 from a first or retracted position within the shifting tool tubular body 202 as illustrated in FIG. 8 to a second or extended position for engagement on the sliding sleeve 44 as discussed above as illustrated in FIG. 9. The parallel shafts also include helical springs (not shown) thereon to bias the sleeve engaging members to the retracted position.

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[0052] The first end 204 of the shifting tool 200 includes an internal threading 236 therein for connection to the external threading of the end of a production string or pipe (not shown). The second end 206 of the shifting tool 200 includes external threading 238 for connection to internal threading of a downstream productions string or further tools, such as by way of non-limiting example a control valve as will be discussed below. An end cap 240 may be located over the external threading 238 when such a downstream connection is not utilized.

[0053] With reference to FIGS. 8 and 9, a first control valve 300 according to a first embodiment located within a shifting tool 200 for use in wells having low hydrocarbon production flow rates. The low flow control valve 300 comprises a valve housing 302 having a valve passage 304 therethrough and seals 344 therearound for sealing the valve housing 302 within the shifting tool 200. The low flow control valve 300 includes a central housing extension 306 extending axially within the valve passage 304 and a spring housing portion 320 downstream of the central portion 310. The central housing extension 306 includes an end cap 308 separating an entrance end of the valve passage from a central portion 310 of the valve passage and an inlet bore 322 permitting a fluid to enter the central portion 310 from the valve passage 304.

[0054] The central portion 310 of the valve passage contains a valve piston rod 312 slidably located therein. The valve piston rod 312 includes leading and trailing pistons, 314 and 316, respectively thereon in sealed sliding contact with the central portion 310 of the valve passage. The leading piston 314 forms a first chamber 313 with the end cap 308 having an inlet port 315 extending through the leading piston 314. The valve piston rod 312 also includes a leading extension 318 having an end surface 321 extending from an upstream end thereof and extending through the end cap 308. The valve piston rod 312 is slidable within the central portion 310 between a closed position as illustrated in FIG. 8 and an open position as illustrated in FIG. 9. In the closed position, the second or trailing piston 316 is sealable against the end of the central portion 310 to close or seal the end of the central passage and thereby prevent the flow of a
fluid through the control valve. In the open position as illustrated in FIG. 9, the trailing piston 316 is disengagable from the end of the central portion 310 so as to provide a path of flow, generally indicated at 319, therethrough from the central passage to the spring housing.

[0055] A spring 324 is located within the spring housing 320 and extends from the valve piston rod 312 to an orifice plate 326 at a downstream end of the spring housing 320. The spring 324 biases the valve piston rod 312 towards the closed position as illustrated in FIG. 8. Shims or the like may be provided between the spring 324 and the orifice plate 326 so as to adjust the force exerted by the spring upon the valve piston rod 312. In other embodiments, the orifice plate may be axially moveable within the valve body by threading or the like to adjust the force exerted by the spring. In operation, fluid pumped down the production string to the valve passage 304 passes through the inlet bore and into the central portion 310. The pressure of the fluid within the central portion 310 is balanced upon the opposed faces of leading and trailing pistons 314 and 316 such that the net pressure exerted upon the valve piston rod 312 is provided by the pressure exerted on the end surface 321 of the leading extension 318 and on the leading piston 314 from within the first chamber 313. The resulting force exerted upon the end surface 321 is resisted by the biasing force provided by the spring 324 as described above.

[0056] Additionally, the orifice plate 326 includes an orifice 328 therethrough selected to provide a pressure differential thereacross under a desired fluid flow rate. In this way, when the fluid is flowing through the central portion 310 and the spring housing 320, the spring housing 320 will have a pressure developed therein due to the orifice plate. This pressure developed within the spring housing 320 will be transmitted through apertures 330 within the spring housing to a sealed region 332 around the spring housing proximate to the shifting bore 226 of the shifting tool 200. This pressure serves to extend the pistons 224 within the shifting bores 226 and thereby to extend the sleeve engaging members 208 from the shifting tool. The pressure developed within the spring housing 320 also resists the opening of the valve piston rod 312 such that
in order for the valve to open and remain open, the pressure applied to the 
entrance of the valve passage 304 is required to overcome both the biasing force 
of the spring 324 and the pressure created within the spring housing 320 by the 
orifice 328.

[0057] The valve 300 may be closed by reducing the pressure of the 
supplied fluid to below the pressure required to overcome the spring 324 and the 
pressured created by the orifice 328 such that the spring is permitted to close the 
valve 300 by returning the valve piston rod 312 to the closed position as illustrate 
in 11 as well as permitting the springs on the parallel shaft 230 to retract the 
sleeve engaging members 208 as the pressure within the spring housing 320 is 
reduced. Seals 336 as further described below may also be utilized to seal the 
contact between the spring housing 320 and the interior of the central bore 210 
of the shifting tool 200.

[0058] A shear sleeve 340 may be secured to the outer surface of the 
valve housing 302 by shear screws 342 or the like. The shear sleeve 340 is sized 
and selected to be retained between a pipe threaded into the internal threading 
236 of the shifting tool 200 and the remainder of the shifting tool body. In such a 
way, should the valve be required to be retrieved, a spherical object 334, such as 
a steel ball, such as are commonly known in the art may be dropped down the 
production string so as to obstruct the valve passage 304 of the valve 300. Obstructing the flow of a fluid through the valve passage 304 will cause a 
pressure to develop above the valve so as to shear the shear screws 342 and 
force the valve through the shifting tool. The strength of the shear screws 342 
may be selected so as to prevent their being sheered during normal operation of 
the valve 300 such as for pressures of between 1000 and 3000 psi inlet fluid 
pressure. The valve illustrated in FIGS. 8 and 9 is adapted for use in a low 
hydrocarbon flow rate well. In such well types, the flow of fluids such as 
hydrocarbons or other fluids is low enough that the fluid pumped down the well to 
pressurize the central portion 310 is sufficient to overcome the flow of the fluids 
up the well so as to pass through the orifice 328. It will be appreciated that for
wells of higher well pressure or flow rates, such a valve will be limited in its application.

[0059] Turning now to Figures 11 and 12, a system for pressurizing the shifting tool 200 is illustrated within the production tubing 20. In operation, as will be described further below, the shifting tool may be formed with a reservoir 500 operable to contain a fluid above the activation pressure of the shifting tool. The tool string 510 may include an isolation element 502 operable to selectably retain a fluid pressure within the reservoir 500 after it has been reduced within the tool string 510 such that the tool string may be moved in a lower pressure state thereby reducing wear and stress thereon. In particular as illustrated in Figure 11, the reservoir may be initially pressurized to extend the shifting keys on the shifting tool. Thereafter the pressure above the reservoir 500 may be reduced while maintaining the pressure within the reservoir by the isolation element 502 and moved as illustrated in Figure 12. Thereafter, the pressure within the reservoir 500 may be released by a release element 504 downstream of the shifting tool 200.

[0060] Turning now to Figure 13, a cross sectional view of the shifting tool and reservoir assembly is illustrated. The tool string is formed with an inner mandrel 520 and an outer housing 530 forming a cavity 522 therebetween. The cavity 522 spans the shifting tool 200 and is adapted to retain the outer housing at an extended position relative to the inner mandrel under pressure of a fluid contained therein and be released therefrom at a controlled rate to release the outer housing 530 relative to the inner mandrel thereby releasing the pressure applied to the shifting tool 200. In such a manner the shifting tool 200 may be maintained at a pressurized while the tool string state is allowed to reduce to a lower pressure for movement thereof.

[0061] Turning now to Figures 14 and 15 the inner mandrel 520 includes an end wall 524 extending therefrom into engagement with the outer housing 530. The inner mandrel 530 also includes a lead protrusion 526 extending annularly outward therefrom wherein the cavity 522 is formed between the lead protrusion 526 and the end wall 524. The outer housing 530 includes a bypass
protrusion 532 extending radially inward therefrom at a position adapted to engage against the end protrusion 526 extending from the inner mandrel. As illustrated one or both of the bypass protrusion 532 or end protrusion 526 may include a seal 534 for sealing the contact between the bypass protrusion 532 and end protrusion 526. Similarly, the end wall 524 includes a seal 528 at a position therein adapted to engage upon and seal the end wall against the outer housing. The bypass protrusion 532 includes at least one bypass passage 540 extending therethrough to permit fluid to escape therefrom through the fluid within the cavity 522.

At a first or closed position as illustrated in Figure 14, the bypass protrusion 532 and lead protrusion 526 are aligned so as to enclose the cavity 522 therebehind. As illustrated in Figure 15, the inner mandrel is longitudinally movable relative to the outer housing in a direction indicated at 550 to a second position to disengage the bypass protrusion 532 from the lead protrusion 526 such that fluid is permitted to flow out of the cavity 522 in a direction generally indicated at 552.

In operation, the shifting tool 200 may be located at the desired location. Thereafter, the inner mandrel 520 may be positioned relative to the outer housing 530 at the initial position as illustrated in Figure 14 with the bypass protrusion 532 and lead protrusion 526 aligned. Thereafter, the cavity 522 may be pressurized with the fluid so as to engage the shifting tool as set out above. Optionally, the cavity 522 may be pressurized before the bypass protrusion 532 and lead protrusion 526 are aligned to seal the cavity 522. In this position, the shifting tool will be engaged upon a sleeve valve permitting the sleeve to be opened or closed as desired by an operator. For such movement, the annulus, generally indicated at 560 as the annual region between the inner mandrel 520 and the outer housing 530 above the may be depressurized so as to depressurize the tool string for such movement in a depressurized state. It will be appreciated that such depressurized state will reduce wear and damage to the tool string during such movement.

After the annulus 560 of the tool string has been depressurized, the fluid within the cavity 522 will be permitted to escape therefrom through the
bypass passage 540. The size of the bypass passage 540 will be selected such that the rate of fluid escape therefrom will be low so as to retain a sufficient volume of fluid within the cavity 522 to keep the cavity 522 at a pressure to keep the shifting tool activated as well as to prevent the volume of the cavity 522 from significantly decreasing. During this period, the inner mandrel 520 may be pulled in a direction generally indicated at 562 such that the pressure within the cavity 522 will maintain the relative positions between the inner mandrel 520 and outer housing 530. While the inner mandrel is pulled in the direction 560, fluid within the cavity will, as set out above maintain the positions between the inner mandrel and outer housing. During this movement, after the pressure within the annulus 560 is reduced the fluid within the cavity 522 escapes from the cavity 522 through the bypass passage 540 at a controlled rate thereby reducing the pressure within the cavity. When the pressure within the cavity 522 reaches a predetermined level, the bypass protrusion 532 will be permitted to move relative to the lead protrusion 526 to an amount sufficient to disengage the two protrusions from each other as illustrated in Figure 15 whereupon the remaining fluid may escape from the cavity 522 in a direction generally indicated at 552. After this remaining fluid has escaped the shifting tool will be disengaged. It will be appreciated that the size of the bypass passage 540 will be selected to provide a desired time delay to keep the shifting tool activated.

[0065] While the present disclosure has been disclosed with respect to a limited number of embodiments, those skilled in the art, having the benefit of this disclosure, will appreciate numerous modifications and variations there from. It is intended that the appended claims cover such modifications and variations as fall within the true spirit and scope of the disclosure.
CLAIMS
What is claimed is:
1. An apparatus for selectably engaging a longitudinally slidable sleeve within a well comprising:
   a tool string slidably beatable within said well;
   a shifting tool slidably beatable within said sleeve at an end of a tool string said shifting tool having a central bore therethrough and keys operable to be extended from an outer surface of said shifting tool when said central bore is supplied with said fluid above a predetermined pressure, said keys being engagable upon said sleeve so as to permit said shifting tool to move said sleeve longitudinally within said tubular body;
   a reservoir in fluidic communication with said central bore of said shifting tool and being operable to contain and hold a quantity of a fluid at a predetermined pressure sufficient to actuate said shifting tool.

2. The apparatus of claim 1 further comprising an isolation body adapted to retain said fluid in said reservoir after said pressure has been reduced in said tool string.

3. The apparatus of claim 2 wherein said isolation body comprises a check valve adapted to permit a flow of fluid into said reservoir in a downward direction only.

4. The apparatus of claim 3 wherein said check valve is located above said shifting tool.

5. The apparatus of claim 1 wherein said reservoir is formed between an inner mandrel and an outer housing of said tool string.

6. The apparatus of claim 5 wherein said inner mandrel and outer housing are longitudinally movable relative to each other along said tool string.
7. The apparatus of claim 6 wherein said outer housing is operably connected to said tool and wherein said inner mandrel is operably connected to a pipe extending to a ground level of said well.

8. The apparatus of claim 7 wherein said reservoir is formed between an end wall and a lead protrusion extending radially outward from said inner mandrel.

9. The apparatus of claim 8 wherein said end wall slidably seal against said outer housing.

10. The apparatus of claim 8 wherein said outer housing includes a bypass protrusion extending radially inwardly therefrom at a position adapted to seal against said lead protrusion of said inner mandrel when said inner mandrel and outer housing are at a first position relative to each other.

11. The apparatus of claim 10 wherein said bypass protrusion is adapted to longitudinally disengage from said lead protrusion as said inner mandrel is slidably displaced relative to said outer housing so as to compress said reservoir.

12. The apparatus of claim 10 wherein said bypass protrusion includes a bleed passage therethrough sized to permit a predetermined flow rate of fluid therethrough.

13. A method for selectably engaging a longitudinally slidable sleeve within a well comprising:
   providing a tool string slidably locatable within said well;
   providing a shifting tool slidably locatable within said sleeve at an end of a tool string said shifting tool having a central bore therethrough and keys operable to be extended from an outer surface of said shifting tool when said central bore is supplied with said fluid above a predetermined
pressure, said keys being engagable upon said sleeve so as to permit said shifting tool to move said sleeve longitudinally within said tubular body; and providing a reservoir in fluidic communication with said central bore of said shifting tool and being operable to contain and hold a quantity of a fluid at a predetermined pressure sufficient to actuate said shifting tool.

14. A method for selectably engaging a longitudinally slidable sleeve within a well comprising:

locating a tool string having a shifting tool therein within said well, wherein said shifting tool has a central bore therethrough and keys operable to be extended from an outer surface of said shifting tool when said central bore is supplied with said fluid above a predetermined pressure, said keys being engagable upon said sleeve so as to permit said shifting tool to move said sleeve longitudinally within said tubular body;

pressurizing a reservoir in fluidic communication with said central bore of said shifting tool and being operable to contain and hold a quantity of a fluid at a predetermined pressure sufficient to actuate said shifting tool to extend said keys from said outer surface of said shifting tool into engagement with a sleeve valve;

reducing said pressure in said tool string above said reservoir; and slidably displacing said shifting tool and sleeve valve within said well by displacing said tool string therein.
INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/066747

A. CLASSIFICATION OF SUBJECT MATTER
E21B ... o f Korea
Facsimile No. +82-42-481-8578 Telephone No. +82-42-481-8440
Form PCT/ISA/210 (second sheet) (January 2015)

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
E21B 23/00; E21B 34/06; E21B 47/00; E21B 34/00; E21B 34/12; E21B 34/14; E21B 43/26; E21B 43/17

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: shifting tool, sleeve valve, reservoir, isolation body, check valve, mandrel, lead protrusion, bypass

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>WO 2014-140609 A2 (PETROWELL LIMITED) 18 September 2014 See page 16, lines 20-22, page 26, line 23 - page 28, line 22 and figures 1, 5A, 5b.</td>
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<td>US 2009-0139726 A1 (GOMES, ALFREDO) 04 June 2009 See paragraphs [0028]-[0032] and figures 1-4.</td>
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<td>A</td>
<td>US 2013-019975 A1 (HALLIBURTON ENERGY SERVICES, INC.) 08 August 2013 See paragraphs [0015]-[0025] and figures 2A-2D.</td>
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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)
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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search
10 April 2017 (10.04.2017)

Date of mailing of the international search report
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