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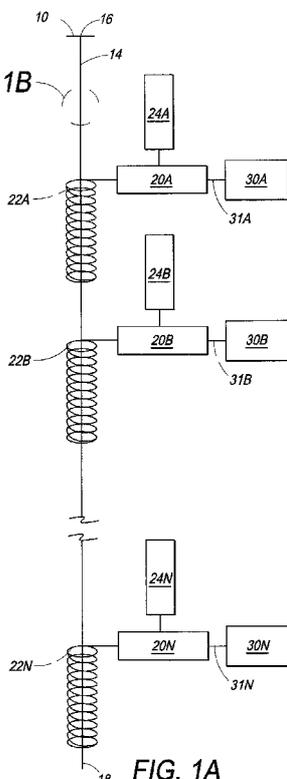
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(54) Title: SYSTEMS, ASSEMBLIES AND PROCESSES FOR CONTROLLING TOOLS IN A WELL BORE



(57) Abstract: A dedicated hydraulic line for transmission of a signal device capable of generating one or more unique signals to one or more tools within a subterranean well. Each tool can be equipped with a reader device for receiving signals from and transmitting signals to the signal device. Each reader device can control operation of the tool associated therewith if the reader device is programmed to respond to signals received from the control device. Hydraulic fluid used to operate the tool can be conveyed via the dedicated hydraulic line or a separate hydraulic line. A separate hydraulic line can be used to reset the tool. Where the tools include sliding sleeves, the tools can be used to hydraulically fracture subterranean environs at spaced apart locations along a well bore in any desired sequence and without removing the tools from the well during the fracturing process.

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## SYSTEMS, ASSEMBLIES AND PROCESSES FOR CONTROLLING TOOLS IN A WELL BORE

### 5 REFERENCE TO RELATED PATENT APPLICATION:

This application is a continuation-in-part of copending U.S. patent application serial no. 12/044,087 filed on March 7, 2008 and entitled "Systems, Assemblies and Processes for Controlling Tools in a Well Bore".

10

## BACKGROUND OF THE INVENTION

### FIELD OF THE INVENTION:

15 The present invention relates to systems, assemblies and processes for controlling equipment, tools and the like that are positioned in a subterranean well bore, and more particularly, to systems, assemblies and processes for controlling a plurality of equipment, tools and the like that are positioned in a subterranean well bore.

20

### DESCRIPTION OF RELATED ART:

In the production of fluid from subterranean environs, a well bore is drilled so as to penetrate one or more subterranean zone(s), horizon(s) and/or formation(s). The well is typically completed by positioning casing which can  
25 be made up of tubular joints into the well bore and securing the casing therein by any suitable means, such as cement positioned between the casing and the walls of the well bore. Thereafter, the well is usually completed by conveying a perforating gun or other means of penetrating casing adjacent the zone(s), horizon(s) and/or formation(s) of interest and detonating  
30 explosive charges so as to perforate both the casing and the zone(s), horizon(s) and/or formation(s). In this manner, fluid communication is established between the zone(s), horizon(s) and/or formation(s) and the interior of the casing to permit the flow of fluid from the zone(s), horizon(s) and/or formation(s) into the well. Alternatively, the well can be completed as  
35 an "open hole", meaning that casing is installed in the well bore but terminates above the subterranean environs of interest. The well is subsequently

equipped with production tubing and convention associated equipment so as to produce fluid from the zone(s), horizon(s) and/or formation (s) of interest to the surface. The casing and/or tubing can also be used to inject fluid into the well to assist in production of fluid therefrom or into the zone(s), horizon(s) and/or formation (s) to assist in extracting fluid therefrom.

Often during the drilling and completion of a well or during production or injection of fluid from or into a well or subterranean environs, it can be desirable to control the operation of multiple tools, equipment, or the like, for example perforating guns, cutters, packers, valves, sleeves, etc., that can be positioned in a well. In the production of fluid from or injection of fluid into subterranean environs, multiple tools and equipment are often positioned and operated in a well bore. For example, a plurality of perforating guns can be deployed within a well bore to provide fluid communication between multiple zones, horizons and/or formations. Upon detonation, these guns fire projectiles through casing cemented within the well bore to form perforations and establish fluid communication between the formation and the well bore. Often these perforating guns are detonated in sequence. A plurality of flapper valves can be used in conjunction with multiple perforating guns to isolate the zone, horizon or formation being completed from other zones, horizons and/or formations encountered by the well bore. As another example, packers can be deployed on a tubular and expanded into contact with casing to provide a fluid tight seal in the annulus defined between the tubular and the casing. Flow chokes can be used to produce the well from multiple zones with these chokes set at different openings to balance the pressure existing between multiple subterranean zones, horizons and/or formations so that a plurality of such zones, horizons and/or formations can be produced simultaneously.

Hydraulic systems have been used to control the operation of tools positioned in a well. Such systems have a control system and a down hole valve. The control system includes surface equipment, such as a hydraulic tank, pump, filtration, valves and instrumentation, control lines, clamps for the control lines, and one or more hydraulic controller units. The control lines run from the surface equipment to and through the wellhead and tubing hanger to desired equipment and tools in the well. These control lines are clamped usually along a tubular that is positioned within a well. The control lines can

be connected to one or more hydraulic control units within a well for distributing hydraulic fluid to the down hole valves.

Several basic arrangements of hydraulic control lines are used in a well. In a direct hydraulic arrangement, each tool that is to be controlled will have two dedicated hydraulic lines. The "open" line extends from the surface equipment to the tool and is used for transporting hydraulic fluid to the downhole control valve to operate the tool, while the "close" line extends from the tool to the surface equipment and provides a path for returning hydraulic fluid to the surface of the earth. The practical limit to the number of tools that can be controlled using the direct hydraulic arrangement is three, i.e. six separate hydraulic lines, due to the physical restraints in positioning hydraulic lines in a well. The tubing hanger through which the hydraulic lines run also has to accommodate lines for a gauge system, at least one safety valve and often a chemical injection line, which limits the number of hydraulic lines the hanger can accommodate. When it is desirable to control more than three tools in a well, a common close arrangement can be employed in which an open line is run to each tool to be controlled and a common close line is connected to each tool to return hydraulic fluid to the surface. Again, the common close system has a practical limit of controlling five tools, i.e. six separate hydraulic lines.

In another arrangement, a single hydraulic line is dedicated to each tool and is connected to each tool via a separate, dedicated controller for each tool. To open the tool, the hydraulic fluid in the dedicated line is pressurized to a first level. Thereafter, the hydraulic fluid in the dedicated line is pressurized to a higher level so as to close the tool. In a digital hydraulics system, two hydraulic lines are run from the surface equipment to a downhole controller that is connected to each of the tools to be controlled. Each controller is programmed to operate upon receiving a distinct sequence of pressure pulses received through these two hydraulic lines. Each tool has another hydraulic line is connected thereto as a common return for hydraulic fluid to the surface. The controllers employed in the single line and the digital hydraulics arrangements are complex devices incorporating numerous elastomeric seals and springs which are subject to failure. In addition, these

controllers use small, inline filters to remove particles from the hydraulic fluid that might otherwise contaminate the controllers. These filters are prone to clogging and collapsing. Further, the complex nature of the pressure sequences requires a computer operated pump and valve manifold which is  
5 expensive.

In accordance with the "distribution hub" arrangement, two hydraulic lines are run from the surface to one downhole controller to which each tool to be controlled is connected by its own set of two hydraulic lines. This controller can be ratcheted to any of a number of predetermined locations,  
10 each of which connects the control lines of a given tool to the control lines running from the surface to the controller. In this manner, each tool can be operated independently from the surface. By ratcheting the controller to another location, another tool can be operated. This arrangement is expensive due to the large number of components and complex arrangement  
15 of seals in the controller and unreliable as it is difficult to get feedback to the surface on the exact position of the controller, especially if the operator has lost track of the pulses previously applied. Thus, a need exists for hydraulic control systems, assemblies and processes for use in controlling multiple tools in a well which is relatively inexpensive, simple in construction and  
20 operation and reliable.

Further, it is often desirable to stimulate the subterranean environs of interest to enhance production of fluids, such as hydrocarbons, therefrom by pumping fluid under pressure into the well and the surrounding subterranean environs of interest to induce hydraulic fracturing thereof. Thereafter, fluid  
25 can be produced from the subterranean environs of interest, into the well bore and through the production tubing and/or casing string to the surface of the earth. Where it is desired to stimulate or fracture the subterranean environs of interest at multiple, spaced apart locations along a well bore penetrating the environs, fluid is pumped into a particular location adjacent the subterranean  
30 environs of interest that is farthest from the surface of earth while a means, such as a flapper valve(s), is employed to isolate the remaining locations. Once fluid is pumped under pressure from the surface into the well and the lowermost location, means are actuated to isolate the next location which is

closest to the surface from the lowermost location and the remaining locations. Fluid is pumped under pressure from the surface into the well and the subterranean environs adjacent the isolated location so as to hydraulically fracture the same. In this manner, all of the subterranean environs adjacent  
5 to the multiple, spaced apart locations can be hydraulically fractured in sequence beginning at the location that is farthest from the surface along the well bore. Conventional systems and associated methodology that are used to stimulate subterranean environs in this manner include casing conveyed perforating systems, ball drop systems, and perforate and plug systems.

10 However, problems exist with hydraulically fracturing subterranean environs from multiple, spaced apart locations in sequence beginning with location that is farthest from the surface along the well bore. Hydraulic fracturing of subterranean environs creates stress forces in rock that essentially harden the particular regions of the subterranean formation  
15 fractured thereby inhibiting propagation of fractures created during hydraulic fracturing of an adjacent region into the region previously fractured. This can cause hydraulic fractures formed in the adjacent region to propagate away from the previously fractured region which may not be desirable. Accordingly, a need exists for a process for sequentially fracturing subterranean environs  
20 from spaced apart locations along the well bore in any desired sequence. A further need exists for a process for sequentially fracturing subterranean environs from spaced apart locations along the well bore in a sequence calculated to advantageously use rock stress generated in the subterranean environs to propagate fractures in a desired manner.

25

### SUMMARY OF THE INVENTION

To achieve the foregoing and other objects, and in accordance with the purposes of the present invention, as embodied and broadly described herein,  
30 one characterization of the present invention is a hydraulic control system for use in a subterranean well is provided. The control system comprises a control line positioned in a subterranean well and extending adjacent at least one tool positioned within the subterranean well. The control line is sized to

permit passage of a control device and each of the at least one tool has a reader device connected thereto.

5 In another characterization of the present invention, a process is provided for conveying at least one control device capable of generating one or more unique signals through a control line positioned in a subterranean well so as to control the operation of at least one tool positioned in the well outside of the control line.

10 In yet another characterization of the present invention, a process is provided for conveying hydraulic fluid via a first hydraulic line to at least one tool positioned in a subterranean well to control the operation of the tool. At least one control device is conveyed through a control line positioned in the well and outside of the first hydraulic line and the at least one tool. Each of the at least one control device is capable of generating one or more unique  
15 signals for controlling flow of hydraulic fluid from the first hydraulic line to the at least one tool.

In a further characterization of the present invention, a process is provided for fracturing a subterranean environs penetrated by a well at spaced apart locations along the well using tools that remain in the well. The  
20 sequence of fracturing comprises fracturing the subterranean environs at one of the spaced apart locations after fracturing the subterranean environs at another of the spaced apart locations which is closer to the surface of the earth along the well.

In a still further characterization of the present invention, a process is  
25 provided that comprises pumping fluid through casing positioned in a well and an opening in a first tool secured to the casing at a pressure sufficient to fracture a portion of a subterranean environs. Thereafter, fluid is pumped through the casing and an opening in a second tool secured to the casing at a pressure sufficient to fracture another portion of the subterranean environs.  
30 The second tool is farther along the well from the surface of the earth than the first tool.

In yet a still further characterization of the present invention, a process is provided that comprises fracturing a first portion of a subterranean environs penetrated by a well at a first location along the well using tools that remain in

the well. Fracturing of the first portion creates rock stress within the first portion. A second portion of said subterranean environs is fractured at a second location along the well using the tools which results in fractures in the second portion that have a geometry influenced by the rock stress present in  
5 the first portion.

### BRIEF DESCRIPTION OF THE DRAWINGS

10 The accompanying drawings, which are incorporated in and form a part of the specification, illustrate the embodiments of the present invention and, together with the description, serve to explain the principles of the invention.

In the drawings:

FIG. 1A is a schematic view of one embodiment of the systems and  
15 assemblies of the present invention that utilizes a dedicated control line;

FIG. 1B is a sectional view of a hydraulic control line of FIG. 1A having a signal device therein;

FIG. 2A is a schematic view of another embodiment of the systems and assemblies of the present invention that utilizes three hydraulic lines that  
20 extend to the surface;

FIG. 2B is a sectional view of a hydraulic control line of FIG. 2A having a signal device therein;

FIG. 3A is a schematic view of a further embodiment of the systems and assemblies of the present invention that utilizes two hydraulic lines that  
25 extend to the surface;

FIG. 3B is a sectional view of a hydraulic control line of FIG. 3A having a signal device therein;

FIG. 4A is a schematic view of still further embodiment of systems and assemblies of the present invention that utilizes one hydraulic line that  
30 extends to the surface;

FIG. 4B is a sectional view of a hydraulic control line of FIG. 3A having a signal device therein;

FIG. 5A is a partially cross sectional illustration of the embodiment of the present invention that utilizes three hydraulic lines as deployed in a subterranean well; and

FIG. 5B is a sectional view of the hydraulic control line of FIG. 5A  
5 having a signal device therein.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As utilized throughout this description, the term "signal control line"  
10 refers to a continuous or jointed line, conduit, tubular or similar structure for conveying fluid and a control device. The substantially axial bore through the control line is sufficient to permit passage of a control device therethrough but the outside diameter of the control line is sufficiently small so as not to impede placement of other lines, tubulars, tools and equipment within the well. A  
15 nonlimiting example of suitable diameters for a signal control line are an outside diameter of from about 0.25 inch to about 0.50 inch and a substantially axial bore diameter of from about 0.15 inch to about 0.40 inch. The diameter of the substantially axial bore through the signal control line used in accordance with the present invention is not sufficient to allow  
20 commercial quantities of formation fluids to be produced therethrough. The signal control line can be constructed of any suitable material, for example stainless steel or a stainless steel alloy. A "signal device" refers to a device which is capable of generating one or more unique signals. Nonlimiting examples of a signal device are a radio frequency identification device (RFID),  
25 a device carrying a magnetic bar code, a radioactive device, an acoustic device, a surface acoustic wave (SAW) device, a low frequency magnetic transmitter and any other device that is capable of generating one or more unique signals. The signal device can have any suitable peripheral configuration and geometric shape, and is sized to permit conveyance  
30 through the signal control line. Some signal devices, for example RFID, can require a peripheral configuration and geometric shape to inhibit tumbling of the RFID during conveyance through the signal control line. A suitable RFID is commercially available from Sokymat SA, Switzerland under the trade

name "Glass Tag 8 mm Q5". A "reader device" refers to a device capable of transmitting signals to and receiving signals from a signal device.

In accordance with one embodiment of the present invention as illustrated in FIG. 1, a signal control line 14 can be positioned in a subterranean well and extend from the well head 10 to a position at least adjacent to the most remote tool from the well head that is desired to be controlled by the processes of the present invention. Although signal control line 14 can be supported from the well head and unattached as positioned in the well, it is preferably secured to tubulars and/or tools positioned in a well by any suitable means, for example by clamps, and can be armored as will be evident to a skilled artisan. Signal control line can be open at end 18 thereof to the well bore. One or more tools or equipment 30A, 30B and 30N can be positioned in a well and can be connected to reader devices 20A, 20B and 20N, respectively. Tools 30A, 30B and 30C can be connected to the associated reader devices 20A, 20B and 20N by any suitable means, such as via a hydraulic or electric line or acoustic connection 31A, 31B and 31N. Each reader device is connected to a suitable power source 24A, 24B, and 24N and antennas 22A, 22B and 22N, respectively. Nonlimiting examples of suitable power sources are batteries. As illustrated, antennas 22 can be coiled to surround control line 10 such that the orientation of signal device 12 within control line 10 is immaterial to the reception of a signal by antenna 22. An unlimited number of tools 30 can be controlled by the present invention, with the total number of tools that are positioned in a well and capable of being controlled by the present invention being designated by the letter "N".

In operation, a suitable signal device 12 can be conveyed from the well head 10 through line 14, for example in suitable fluid, such as hydraulic oil or water, that can be pumped by equipment located at the surface. The signal device 12 is sized and configured to inhibit the signal device from tumbling in line 14 during conveyance (FIG. 1B). Each signal device 12 is programmed to generate a unique signal. Similarly, each reader device 20A, 20B and 20N is programmed to look for a unique code signal. As the signal device 12 passes in proximity to a reader device 20, the unique signal transmitted by signal device 12 can be received by an antenna 22. If a given reader device

20 is programmed to respond to the signal transmitted by the device 12 via the associated antenna 22, the reader device 20 transmits a corresponding control signal to the associated tool 30 to actuate the tool. Reader devices 20 can also transmit signals which in turn are received by and cause signal  
5 device 12 to generate the unique signal.

Each reader device 20 can be programmed to respond to its own unique signal or the same signal of at least one other reader device. As the signal device 12 is conveyed through line 14, the unique signal transmitted thereby can be received and read by each successive reader device. If the  
10 unique signal matches that programmed in the reader device, the reader device transmits a control signal to actuate the associated tool 30. Ultimately, the signal device 12 exits through the end of the control line 14 into the well. Thereafter, one or more additional control devices can be conveyed via control line 14 to actuate one or more tools 30 in any sequence and manner  
15 desired. In this manner, an unlimited number of tools can be actuated by conveying one or more control devices via control line 14. When line 14 is open at end 18 to the well bore, it is subject to hydrostatic fluid, and as such, the hydraulic pressure exerted in this line must be sufficient to overcome this pressure so as to convey signal device 12 through line 14.

20 In accordance with another embodiment of the present invention as illustrated in Fig. 2, three hydraulic lines 114, 154 and 164 can be positioned in a subterranean well and extend from the well head 110 to a position at least adjacent to the most remote tool from the well head that is desired to be controlled by means of this embodiment of the present invention. Each line  
25 114, 154 and 164 has a first end 116, 156, 166, respectively, at or near the well head 110 and a second end 118, 158 and 168 located in the well. Second end 118 or line 114 can be open to the well and therefore the hydrostatic pressure of any fluid that is present in the well, while ends 158 and 168 of lines 156 and 166, respectively, can be capped or plugged as  
30 illustrated in FIG. 1 by any suitable means as will be evident to a skilled artisan. Alternatively, the end 116 of control line 114 can be connected to either end 158 of control line 154 or end 168 of control line 164 to permit the control device 112 to be conveyed through line 114 and back to the surface through line 154 or line 164. Although lines 116, 156 and 166 can be

supported from the well head and unattached as positioned in the well, each line is preferably secured to tubulars and/or tools positioned in a well by any suitable means, for example by clamps, and can be armored as will be evident to a skilled artisan.

- 5 A plurality of tools or equipment 130A, 130B and 130N are positioned in a well and can have a piston or sleeve 132A, 132B and 132N, respectively, moveably secured therein. Each tool 130A, 130B and 130N can be connected to hydraulic line 156 by means of lines 134A, 134B and 134N, respectively, each of which has a corresponding valve 136A, 136B and 136N.
- 10 Reader devices 120A, 120B and 120N are electrically connected to a suitable power source 124A, 124B, and 124N and antennas 122A, 122B and 122N, respectively. Nonlimiting examples of suitable power sources are batteries. These power sources can be preprogrammed to be in a sleep mode except for certain predetermined periods of time so as to conserve power
- 15 consumption and therefore extend the life of the power source. As illustrated antennas 122A, 122B and 122N are coiled to surround control line 114 such that the orientation of the signal device 112 within control line 114 is immaterial. Each reader device 120A, 120B and 120N can be electrically connected to corresponding motors 126A, 126B and 126N, respectively,
- 20 which in turn drive shaft or stem 127A, 127B and 127N to open or close valves 136A, 136B and 136N as will be evident to a skilled artisan. An unlimited number of tools 130 can be controlled by this embodiment of the present invention, with the total number of tools that are positioned in a well and capable of being controlled being designated by the letter "N". Hydraulic
- 25 fluid, such as hydraulic oil or water, can be used in each of the three hydraulic lines and can be pressurized by any suitable means, such as a pump located at or near the well head, to a pressure sufficient to overcome the hydrostatic pressure of fluid present in the well to move from the well head through fluid and signal device 112 a hydraulic line and into the well.
- 30 As typically positioned in a well, valves 136A, 136B and 136 N are in a closed positioned and pistons 132A, 132B and 132N are positioned to one end of the respective tool 130 as noted by the positions x or y in Fig. 2. While the tools 130 are illustrated in Fig. 2 as having a position generally on each

end and in the center of the tool, the piston can be able to achieve several positions along the tool and have an associated mechanism, such as a collet, to allow this to be accomplished. A nonlimiting example of a tool utilizing a piston having variable positions is a variable choke installed in a tubular  
5 positioned in a well.

In operation, a suitable signal device 112 can be conveyed from the well head 110 through line 114, for example in fluid pumped by equipment located at the surface. Each signal device 112 is programmed to generate a unique signal. Similarly, each reader device 120A, 120B and 120N is  
10 programmed to look for a unique code signal. As the signal device 112 passes in proximity to a given reader device 120, the unique signal transmitted by signal device 112 can be received by an antenna 122. If a given reader device 120 is programmed to respond to the signal transmitted by the device 112 via the associated antenna 122, the reader device 120  
15 transmits a corresponding control signal to the associated motor 126 which in turn causes valve 136 to open via shaft 127. Reader devices 120 can also transmit signals which in turn are received by and cause signal device 112 to generate the unique signal. As hydraulic fluid in line 154 is thereby permitted to flow through line 134 and valve 136, the pressure of the hydraulic fluid  
20 causes piston 132 in tool 130 to move to the desired position and thereby actuate the tool. Movement of the piston 132 in tool 130 causes the hydraulic fluid on the other side of piston 132 to flow back to the well head 110 via hydraulic line 164. To move piston 132 to a different position, pressure on the hydraulic fluid in line 154 or line 164 can be increased to move the piston with  
25 the associated mechanism, such as a collet, thereby permitting the piston to sequentially achieve several positions along the tool 130.

Each reader device 120 can be programmed to respond to its own unique signal or the same signal of at least one other reader device. As the signal device 112 is conveyed through line 114, the unique signal transmitted  
30 thereby can be received and read by each successive reader device. If the unique signal matches that programmed in the reader device, the reader device transmits a control signal to open the associated motor 126 and valve 136. Ultimately, the signal device 112 exits through the end of the control line 114 into the well. Thereafter, one or more additional signal devices 112 can

be conveyed via control line 114 to actuate one or more motor(s) 126 and valve(s) 136 in any sequence and manner desired. In this manner, an unlimited number of tools 130 can be actuated by conveying one or more control devices via control line 114. As line 114 is open at end 118 to the well bore, it is subject to hydrostatic fluid and as such the hydraulic pressure exerted in this line must be sufficient to overcome this pressure so as to convey signal device 112. Alternatively, line 114 can be connected to line 158 thereby permitting passage of signal device 112 to the surface. Signal device 112 can be configured to receive a signal from a given reader device that the unique signal conveyed by the signal device was received by the reader device. In this instance, the reader devices 120 are transceivers permitting each device to receive a unique signal from the signal device and to transmit another unique signal back to the signal device. Each signal device 112 can also be equipped with suitable gauges to measure well, formation, and/or fluid conditions which can then be recorded in signal device 112. Nonlimiting examples of suitable gauges are temperature and pressure gauges. Information contained in the signal device 112 can be read at the surface, erased from the signal device 112, if desired, and the signal device can be programmed to emit another unique signal for use in the same well or another well.

To close each valve 136, each associated reader device can be preprogrammed to actuate the appropriate motor 126 and shaft 127 after a period of time to close the associated valve 136. Alternatively, a signal device 112 can be conveyed via line 114 to transmit a unique signal to the appropriate reader device 120 via antenna 122 which in turn transmits a corresponding control signal to the associated motor 126 causing shaft 127 to close valve 136.

In accordance with another embodiment of the present invention as illustrated in Fig. 3, two hydraulic lines 214 and 264 are positioned in a subterranean well and extend from the well head 110 to a position at least adjacent to the most remote tool from the well head that is desired to be controlled by means of this embodiment of the present invention. Lines 214 and 264 have a first end 216 and 266, respectively, at or near the well head

210 and a second end 218 and 268 secured and in fluid communication with a line 270. Although lines 216 and 266 can be supported from the well head and unattached as positioned in the well, each line, including line 270, is preferably secured to tubulars and/or tools positioned in a well by any suitable means, for example by clamps, and can be armored as will be evident to a skilled artisan.

In the embodiment of the present invention illustrated in Fig. 3, valves 236A, 236B and 236N are initially in the closed position as the system is deployed in a well, while valve 290 in line 270 connecting the lower ends of 218, 268 of lines 214 and 264 together is initially in the open position. To begin operation, a unique signal device 212 can be conveyed via line 214 by any suitable means, for example hydraulic oil. The unique signal transmitted by signal device 212 can be received by each antenna 222 and conveyed to each associated reader device 220. If a given reader device has been preprogrammed to respond to the received signal, that reader device actuates motor 226 to open valve 236 via shaft 227. The signal device then passes through line 270 and conveys a signal to reader device 280 via antenna 282. Reader device 280, which can be powered by power source 284, in turn activates motor 296 to close valve 290 via shaft 297. Each signal device can be configured to receive a signal from a given reader device that the unique signal conveyed by the signal device was received by the reader device. In this instance, the reader devices 220 are transceivers permitting each device to receive a unique signal from the signal device and to transmit another unique signal back to the signal device. Each signal device 212 can also be equipped with suitable gauges to measure well, formation, and/or fluid conditions which can then be recorded in signal device 212. Nonlimiting examples of suitable gauges are temperature and pressure gauges. With valve 290 closed, hydraulic fluid can be directed via line 214 to that valve(s) 236 that was opened by the unique signal device 212 to move piston 232 to a desired position. Valves 236A, 236B and 236N are in a closed positioned and pistons 232A, 232B and 232N are positioned to one end of the respective tool 230 as noted by the positions x or y in Fig. 3. While the tools 230 are illustrated in Fig. 3 as having a position generally on each end and in the center of the tool, the piston can be able to achieve several positions along

the tool and have an associated mechanism, such as a collet, to allow this to be achieved. Reader device 280 can be programmed to cause valve 290 to open a predetermined time after being closed or the unique signal(s) from signal device 212 can contain instructions to cause the reader device to open  
5 valve 290 in a predetermined amount of time. Once valve 290 is open, signal device 212 can be conveyed to the well head 210 via line 264 by pressurizing hydraulic fluid in line 214. Information contained in the signal device 212 can be read at the surface, erased from the signal device 212, if desired, and the signal device can be programmed to emit another unique signal for use in the  
10 same well or another well.

In the embodiment of the present invention illustrated in Fig. 4, one hydraulic line 314 can be positioned in a subterranean well and extends from the well head 310 to a position at least adjacent to the most remote tool from the well head that is desired to be controlled by means of this embodiment of  
15 the present invention. Line 314 has a first end 316 at or near the well head 310 and a second end 318 open to the well. Hydraulic line 314 is also equipped with a valve 390 which is initially in an open position. Although line 314 can be supported from the well head and unattached as positioned in the well, line 314 is preferably secured to tubulars and/or tools positioned in a well  
20 by any suitable means, for example by clamps, and can be armored as will be evident to a skilled artisan. One or more tools 330 are positioned in the well by means of continuous or jointed tubulars or wireline. The letter "N" represents the total number of tools and associated equipment that are positioned in the well and assembled as capable of being controlled in  
25 accordance with the system and process of this embodiment of the present invention. Tools 330 are connected to hydraulic line 314 by means of associated hydraulic lines 334 and have pistons 332 positioned therein. Pistons 332A, 332B and 332N are positioned to one end of the respective tool 330 as noted by the positions x or y in Fig. 4. While the tools 330 are  
30 illustrated in Fig. 4 as having a position generally on each end and in the center of the tool, the piston can be able to achieve several positions along the tool and have an associated mechanism, such as a collet, to allow this to be achieved. A nonlimiting example of a tool utilizing a piston having variable positions is a variable choke installed in a tubular positioned in a well.

Change-over valves 336 are positioned in hydraulic lines 334 and are connected to and controlled by motors 326 and shafts 327. Reader devices 320A, 320B and 320N are electrically connected to a suitable power source 324A, 324B, and 324N and antennas 322A, 322B and 322N, respectively.

5 Nonlimiting examples of suitable power sources are batteries. These power sources can be preprogrammed to be in a sleep mode except for certain predetermined periods of time so as to conserve power consumption and therefore extend the life of the power source. As illustrated, antennas 322A, 322B and 322N are coiled to surround control line 314 such that the  
10 orientation of the signal device 312 within control line 314 is immaterial. Each reader device 320A, 320B and 320N is electrically connected to corresponding motors 326A, 326B and 326N, respectively, which in turn drive shaft or stem 327A, 327B and 327N to open or close valves 336A, 336B and 336N as will be evident to a skilled artisan.

15 Another reader device 380 is electrically connected to a suitable power source 384 and antenna 382 which is configured to surround hydraulic line 314. Reader device 380 is also electrically connected to motors 396 which drives shaft or stem 397 to open or close valve 390 as will be evident to a skilled artisan.

20 In operation, a signal device 312 can be conveyed via line 314, through open valve 390 and open end 318 into the well for example in fluid pumped by equipment located at the surface. Each signal device 312 is programmed to generate a unique signal. Similarly, each reader device 320A, 320B and 320N is programmed to look for a unique code signal. As the signal device  
25 312 passes in proximity to a given reader device 320, the unique signal transmitted by signal device 312 can be received by an antenna 322. If a given reader device 320 is programmed to respond to the signal transmitted by the device 312 via the associated antenna 322, the reader device 320 transmits a corresponding control signal to the associated motor 326 which in  
30 turn causes valve 336 to open via shaft 327. Reader devices 320 can also transmit signals which in turn are received by and cause signal device 312 to generate the unique signal. Antenna 382 conveys a signal received from signal device 312 to actuate motor 396 and shaft 397 to close valve 390.

Thereafter, hydraulic fluid in line 314 is thereby permitted to flow through line 334 and valve 336 thereby causing piston 332 in tool 330 to move to the desired position and thereby actuate the tool. Hydraulic fluid flowing around a given piston 332 is permitted to flow back into the well via hydraulic line 338.

- 5 Reader device 380 can be programmed to cause valve 390 to open a predetermined time after being closed or the unique signal from signal device 312 can contain instructions to cause the reader device to open valve 390 in a predetermined amount of time.

Fig. 5 illustrates substantially the embodiment of the present invention depicted schematically in Fig. 2 as deployed in a subterranean well. In Fig. 5  
10 a subterranean well 502 extends from the surface of the earth 503 and penetrates one or more subterranean environs 508 of interest. As used throughout this description, the term "environs" refers to one or more subterranean areas, zones, horizons and/or formations that can contain  
15 hydrocarbons. Although the well 502 can have any suitable subterranean configuration as will be evident to a skilled artisan, the well is illustrated in Fig. 5 as having a generally horizontal configuration through the subterranean environs 508 of interest. The well can be provided with intermediate casing 504 which can be secured within the well 502 by any suitable means, for  
20 example cement (not illustrated), as will be evident to a skilled artisan. The intermediate casing is illustrated in Fig. 5 as extending from the surface of the earth to a point near the subterranean environs 508 of interest so as to provide an open hole completion through a substantial portion of the subterranean environs 508 of interest that are penetrated by well 502.  
25 Production casing 506 is also positioned within the well and is sized to extend through the casing and into the open hole of well 502 within the subterranean environs 508. Production casing 506 is further provided with a one or more tools 530A-F which are sliding sleeves as illustrated in Fig. 5 to selectively provide a fluid communication between the environs 508 and the interior of  
30 production casing 506. A control line 114 has a first end 116 at or near the well head 110 and extends in the annulus between the casing and tubing to each of the tools 530 A-F. The other end of 118 of the control line extends into production casing 506. Hydraulic lines 154 and 164 each extend from the surface of the earth at or near the wellbore to at least to a point in the well

adjacent to the distal tool 530 F so as to allow hydraulic connection thereto in a manner is illustrate in Fig. 2. Although lines 116, 156 and 166 can be supported from the well head and unattached as positioned in the well, each line is preferably secured to the exterior of production casing 506 by any  
5 suitable means, for example by clamps, and can be armored as will be evident to a skilled artisan.

In accordance with an embodiment of the fracturing process of the present invention, a control device 112 can be conveyed through control line 114 to selectively, hydraulically operate the sliding sleeves in tools 530 A-F in  
10 a manner as described above with reference to Fig. 2. The arrangement of sliding sleeves depicted in Fig. 5 can be selectively opened to permit hydraulic fracturing of the subterranean environs 508 of interest adjacent the open sleeve(s) in any desired sequence. The sliding sleeves in tools A-F can be opened in any desired sequence and are not limited to being opened in  
15 sequence beginning with the sleeve of the tool positioned farthest from the surface, i.e. the sleeve in tool 530 F. Often it can be advantageous to open the sleeve adjacent the area of subterranean environs 508 farthest from the surface along well 502 last in the sequence where fracturing fluid contains a gas as this gas can energize fluid produced from the subterranean environs  
20 thereby facilitating production thereof. Further, the sliding sleeves in tools 530 A-F can be opened individually or the sliding sleeves in more than one of the tools 530 A-F can be opened at the same time the and the subterranean environs adjacent each opened sleeve can be fractured simultaneously. Once a sleeve is opened, suitable fluid is pumped through casing 506 and the  
25 opened sleeve(s) at a pressure that is sufficient to hydraulically fracture the subterranean environs adjacent the opened sleeve(s). Additionally, the sleeves in one or more of tools 530 A-F can be opened simultaneously or in any sequence during production of fluid from the subterranean environs 508 through casing 502 to the surface 503.

30 The generally annular area 505 between well 502 and production casing 506 typically contains fluid. In addition, fluid can be injected from the surface of the earth 503 via well 502 and positioned in annular area 505 to form a fluid tight barrier which can be broken down at the location of fluid injected during a fracturing operation so as to provide fluid communication

between fractured areas of the subterranean environs 508 and production casing 506 via opened sliding sleeve(s) in tool(s) 530 A-F. The fluid injected into annular areas 505 can be a viscous fluid or a fluid which sets up to form a generally solid barrier. A nonlimiting example of the latter fluid is a crosslinked gel which sets up after being positioned in the annular area and can be formulated so as to break down after a predetermined amount of time. Another nonlimiting example of the latter fluid is cement.

Rock stress generated during fracturing of an area of subterranean environs 508 causes the rock in the fractured area to be resistant to the propagation therein of fractures from a subsequently fractured adjacent area. This rock stress can be used in accordance with another embodiment of the fracturing process of the present invention, to propagate fractures that are subsequently created in the subterranean environs in a desired manner. For example, the area of subterranean environs 508 located adjacent the sleeve in tool 530 D can be fractured and either simultaneously therewith or thereafter the area of subterranean environs 508 located adjacent the sleeve in tool 530 F can be fractured. Subsequently, the area of subterranean environs located adjacent the sleeve in tool 530 E is fractured and, because the previously fractured areas of subterranean environs 508 are resistant to fracture propagation, more energy is directed and the fractures formed in the area surrounding tool 530 E are propagated farther away from the well 502. The sleeves in tools 530 A-F can be opened in any desired sequence to take advantage of rock stress created during the fracturing process to propagate fractures either farther away from the well or in a given axial direction away from the stressed area as will be evident to a skilled artisan.

The following example demonstrates the practice and utility of the present invention, but is not to be construed as limiting the scope thereof.

#### EXAMPLE 1

A well is drilled to total depth (TD) so as to penetrate a subterranean formation of interest and the drilling assembly is removed from the well. A 7 inch outer diameter intermediate casing is positioned in the well to extend substantially from the surface of the earth to a point above the subterranean formation of interest. The intermediate casing is cemented to the well bore by

circulating cement. Excess cement is drilled from the intermediate casing and well bore extending below the intermediate casing through the subterranean zone of interest.

5 A 3.5 inch outer diameter production casing is equipped with 6 sliding sleeves and has 3 hydraulic lines attached to the outside of the production casing. The sliding sleeves are arranged in series and referred to hereafter as sliding sleeves 1-6, with sliding sleeve 1 being proximal and sliding sleeve 6 being distal the intermediate casing. The hydraulic lines are a control line, a hydraulic power open line and a hydraulic power close line. The end of the production casing has a cementing shoe and a check valve assembly. The production casing and associated equipment and lines is lowered into the well until all sleeves which are in the closed position are in the open hole (portion of the well without intermediate casing).

15 Water-based, cross-linked fluids are pumped down the production casing and placed in annulus between the production casing and the open hole from TD to above sliding sleeve 1. The fluids are displaced with wiper plug that is conveyed through the production casing and latches in place at the bottom thereof so as to prevent flow of well fluids into the production casing. The fluids are allowed to thicken and create zonal isolation barriers.

20 A radio frequency identification device (RFID) encoded with specific code is pumped down the control line to actuate the shuttle valve in distal sliding sleeve from the intermediate casing (sleeve 6). Actuation is achieved by means of a radio frequency transceiver associated with the sliding sleeve. Approximately 7 gallons of hydraulic fluid are required to pump the RFID through the control line and into the well. Approximately 3,000 psi pressure is applied via hydraulic fluid in the power open line to open sliding sleeve 6. No pressure should be applied to the power close line so that minor fluid returns can occur as the piston in the sliding sleeve moves positions. After some time period, the shuttle valve in sliding sleeve 6 should close, locking the sleeve in the open position. Thereafter, approximately 3,000 barrels of fluid are pumped through the production casing, open sleeve 6 and into the formation adjacent sliding sleeve 6 so as to fracture and stimulate production of fluids from this adjoining formation. Sand can be incorporated into the stimulation fluid if desired.

Another RFID chip encoded with a specific code down is pumped down control line to actuate the shuttle valve in sliding sleeve 6. Approximately 3,000 psi pressure is applied via hydraulic fluid in the power close line to close sliding sleeve 6. No pressure should be applied to the power open line so that minor fluid returns can occur as the piston in the sliding sleeve moves positions. After some time period the shuttle valve in sliding sleeve 6 should close, locking the sleeve in the closed position. Thereafter, the production casing is pressure tested to confirm integrity. A RFID encoded with a specific code is pumped down the control line to actuate the shuttle valve in sliding sleeve 5. Approximately 3,000 psi pressure is applied to the hydraulic fluid in power open line to open sliding sleeve 5. No pressure should be applied to the power close line so that minor fluid returns can occur as the piston in the sliding sleeve moves positions. After some time period the shuttle valve in sliding sleeve 5 should close, locking the sleeve in the open position.

Thereafter, approximately 3,000 barrels of fluid are pumped through the production casing, open sleeve 5 and into the formation adjacent sliding sleeve 5 so as to fracture and stimulate production of fluids from this adjoining formation. Sand can be incorporated into the stimulation fluid if desired.

Another RFID chip encoded with a specific code down is pumped down control line to actuate the shuttle valve in sliding sleeve 5. Approximately 3,000 psi pressure is applied via hydraulic fluid in the power close line to close sliding sleeve 5. No pressure should be applied to the power open line so that minor fluid returns can occur as the piston in the sliding sleeve moves positions. After some time period the shuttle valve in sliding sleeve 5 should close, locking the sleeve in the closed position. Thereafter, the production casing is pressure tested to confirm integrity. This process is repeated for sliding sleeves 4, 3, 2, and 1 respectively.

After the formation adjacent each of sleeves 1-6 has been stimulated, the cross-linked fluids are permitted to break down thereby removing the isolation barriers. Separate RFIDs are pumped down the control line to open and allow the well to be flow tested sequentially open sleeves 1, 2, 3, 4, 5, and 6 in order, while applying pressure to power open line and holding no back pressure on the power close line. The production casing and associated sleeves and lines can then be retrieved from the well, after circulating fluid

down the production casing and up annulus. Thereafter, the well completion operations are continued.

Although the fracturing process of the present invention has been depicted in Fig. 5 and described above as performed with a control device  
5 112 conveyed through control line 114 to selectively, hydraulically operate the sliding sleeves in tools 530 A-F in a manner as described above with reference to Fig. 2, the fracturing process of the present invention can be practiced with other control means. For example, the control device 112 and control line 114 depicted in Figs. 2 and 5 and described above in relation  
10 thereto can be eliminated and the systems of Figs. 2 and 5 can be operated by sending signals, such as acoustic or electromagnetic signals, to reader device(s) 120A, 120B and 120N via the earth, fluid contained in well 502, or casing 504 or 506 or other tubulars positioned in the well from a suitable source 550 located at the surface of the earth 503. Use of seismic monitoring  
15 equipment can be useful in monitoring fracture propagation in real time operations.

Although the antennae of the present invention has been illustrated in FIGS. 1-4 as being coiled around the control line employed in accordance with the present invention, certain signal devices, such as SAW, may not  
20 require a coiled antenna for the signal transmitted thereby to be received by the associated reader device(s). In such instances, the reader device(s) 20, 120, 220, and 320 can have an antenna that is proximate to control line 14, 114, 214, and 314, respectively. Further, in those embodiments of the present invention where the signal device can be conveyed into the well from  
25 the control line, the signal device can be equipped with suitable gauges, such as temperature and pressure, and conveyed into a subterranean formation surrounding the well. Subsequently, the signal device can be produced with formation fluid into the well and the surface of the earth where the information recorded in the signal device can be read. The systems,  
30 assemblies and processes of the present invention allow a plurality of tools in a well to be controlled via a limited number of hydraulic lines. Nonlimiting examples of tools useful in the systems, assemblies and processes of the present invention are sliding sleeves, packers, perforating guns, flow control devices, such as chokes, and cutters.

While the foregoing preferred embodiments of the invention have been described and shown, it is understood that the alternatives and modifications, such as those suggested and others, can be made thereto and fall within the scope of the invention.

## CLAIMS

We claim:

1. A hydraulic control system for use in a subterranean well comprising:  
a control line positioned in a subterranean well and extending adjacent  
5 at least one tool positioned within the subterranean well, said control line  
being sized to permit passage of a control device and each of said at least  
one tool has a reader device connected thereto.
2. The hydraulic control system of claim 1 wherein said control line has  
one end at or near the surface of the earth.
- 10 3. The hydraulic control system of claim 2 wherein said control line has  
another end that is open to the well.
4. The hydraulic control system of claim 1 wherein said control device is  
capable of generating one or more unique signals.
5. The hydraulic control system of claim 4 wherein said control device is a  
15 radio frequency identification device, a device carrying a magnetic bar code, a  
radioactive device, an acoustic device, a surface acoustic wave device, or a  
low frequency magnetic transmitter.
6. The hydraulic control system of claim 5 wherein said reader device is  
connected to a battery.
- 20 7. The hydraulic control system of claim 5 wherein said reader device has  
an antenna.
8. The hydraulic control system of claim 7 wherein said antenna  
substantially surrounds said control line.
9. The hydraulic control system of claim 8 wherein said antenna is  
25 configured substantially as a coil and said control line extends through said  
coil.
10. The hydraulic control system of claim 1 wherein said at least one tool is  
a plurality of tools.
11. The hydraulic control system of claim 1 wherein said control line is  
30 hydraulically connected to each of said at least one tool.
12. The hydraulic control system of claim 11 wherein each hydraulic  
connection between said control line and said tool is provided with a valve,  
the actuation of said valve capable of being controlled by said reader device.

13. The hydraulic control system of claim 11 further comprising:  
a first hydraulic line positioned in a subterranean well and hydraulically connected to each of said at least one tool positioned within the subterranean well.
- 5 14. The hydraulic control system of claim 13 wherein said control line and said first hydraulic line are connected.
15. The hydraulic control system of claim 13 further comprising:  
a second hydraulic line positioned in a subterranean well and hydraulically connected to each of said at least one tool such that increasing  
10 hydraulic pressure in said first hydraulic line moves a component in said tool one direction while increasing pressure in said second hydraulic line moves said component in an opposite direction.
16. The hydraulic control system of claim 15 wherein said control line and said second hydraulic line are connected.
- 15 17. The hydraulic control system of claim 16 further comprising:  
a valve substantially at the connection of said control line and said second hydraulic line.
18. The hydraulic control system of claim 17 further comprising:  
a second reader device for controlling said valve.
- 20 19. The hydraulic control system of claim 1 wherein said control line is secured to production casing.
20. The hydraulic control system of claim 1 wherein said control line is secured to tubing.
21. A process comprising:  
25 conveying at least one control device capable of generating one or more unique signals through a control line positioned in a subterranean well so as to control the operation of at least one tool positioned in the well outside of the control line.
22. The process of claim 21 further comprising:  
30 discharging said at least one control device from the control line into the well.
23. The process of claim 21 wherein said at least one control device controls the operation of a plurality of tools.

24. The process of claim 21 wherein each of said at least one tool has a reader device connected thereto that is capable of receiving one or more unique signals from each of said at least one control device and controlling the operation of the tool connected thereto upon receipt of specific unique signal that the reader device is programmed to respond to.
25. The process of claim 24 further comprising:  
transmitting a signal from said reader device to said at least one control device.
26. The process of claim 21 wherein said at least one control device is a radio frequency identification device, a device carrying a magnetic bar code, a radioactive device, an acoustic device, a surface acoustic wave device, or a low frequency magnetic transmitter.
27. The process of claim 21 further comprising:  
conveying hydraulic fluid via said control line for operation of said at least one tool, said one or more unique signals from said at least one control device capable of controlling the flow of said hydraulic fluid to said at least one tool.
28. The process of claim 27 further comprising:  
conveying hydraulic fluid to said at least one tool via a hydraulic line positioned in the well so as to reset said tool after hydraulic fluid is conveyed via said control line.
29. The process of claim 28 wherein said control line is connected to said hydraulic line in the well, the process further comprising:  
conveying said at least one control device to the surface of the earth.
30. The process of claim 28 further comprising:  
transmitting a signal from said reader device to said at least one control device.
31. The process of claim 30 further comprising:  
measuring well, formation, fluid conditions or combinations thereof by means of gauges that said at least one signal device is equipped with.
32. The process of claim 31 wherein said control line is connected to said hydraulic line in the well, the process further comprising:  
conveying said at least one control device to the surface of the earth.

33. A process comprising:  
conveying hydraulic fluid via a first hydraulic line to at least one tool positioned in a subterranean well to control the operation of said tool; and  
conveying at least one control device through a control line positioned  
5 in the well and outside of the first hydraulic line and said at least one tool, each of said at least one control device capable of generating one or more unique signals for controlling flow of said hydraulic fluid from said first hydraulic line to said at least one tool.
34. The process of claim 33 wherein each of said at least one tool has a  
10 reader device connected thereto capable of receiving said one or more unique signals.
35. The process of claim 33 wherein said control line is connected to first hydraulic line in the well, the process of further comprising:  
conveying said at least one control device to the surface of the earth.
- 15 36. The process of claim 34 further comprising:  
transmitting a signal from said reader device to said at least one control device.
37. The process of claim 33 further comprising:  
measuring well, formation, fluid conditions or combinations thereof by  
20 means of gauges that said at least one signal device is equipped with.
38. The process of claim 37 wherein said control line is connected to first hydraulic line in the well, the process further comprising:  
conveying said at least one control device to the surface of the earth  
via said first hydraulic line.
- 25 39. The process of claim 33 further comprising:  
conveying hydraulic fluid to said at least one tool via a second hydraulic line positioned in the well so as to reset said tool after hydraulic fluid is conveyed via said first hydraulic line.
40. The process of claim 39 wherein said control line is connected to said  
30 second hydraulic line in the well, the process further comprising:  
conveying said at least one control device to the surface of the earth  
via said second hydraulic line.
41. A process comprising;

fracturing a subterranean environs penetrated by a well at spaced apart locations along the well using tools that remain in the well and in a sequence comprising fracturing the subterranean environs at one of said spaced apart locations after fracturing the subterranean environs at another of said spaced apart locations which is closer to the surface of the earth along the well.

5

42. The process of claim 41 wherein the well is substantially horizontal through the subterranean environs.

10

43. The process of claim 41 wherein the sequence comprises fracturing the subterranean environs substantially simultaneously from at least two of said spaced apart locations.

44. The process of claim 41 wherein the subterranean environs is one subterranean formation.

15

45. The process of claim 42 wherein the subterranean environs is one subterranean formation.

20

46. The process of claim 41 wherein the sequence comprises fracturing the subterranean environs at one of said spaced apart locations after fracturing the subterranean environs at two of said spaced apart locations that are adjacent to the one of said spaced apart locations, said one of said spaced apart locations being farther from the surface of the earth along the well than at least one of said two of said spaced apart locations.

47. The process of claim 46 wherein the well is substantially horizontal through the subterranean environs.

25

48. The process of claim 46 wherein the subterranean environs is one subterranean formation.

49. The process of claim 47 wherein the subterranean environs is one subterranean formation.

30

50. The process of claim 41 wherein each of said tools comprises a sliding sleeve and the step of fracturing comprising pumping a fluid under pressure through the well bore and the opened sliding sleeve in at least one of said tools and into the subterranean environs.

51. A process comprising:

pumping fluid through casing positioned in a well and an opening in a first tool secured to the casing at a pressure sufficient to fracture a portion of a subterranean environs; and thereafter,

5 pumping fluid through the casing and an opening in a second tool secured to the casing at a pressure sufficient to fracture another portion of the subterranean environs, said second tool being farther along the well from the surface of the earth than the first tool.

52. The process of claim 51 further comprising:

10 producing fluid that is present in the subterranean environs prior to the steps of pumping into the well via said opening in said first tool, said opening in said second tool, or both of said openings in said first tool and said second tool.

53. The process of 51 wherein the well is substantially horizontal through the subterranean environs.

15 54. The process of claim 51 wherein the subterranean environs is one subterranean formation.

55. A process comprising:

20 fracturing a first portion of a subterranean environs penetrated by a well at a first location along the well using tools that remain in the well, said fracturing of said first portion creating rock stress within said first portion; and fracturing a second portion of said subterranean environs at a second location along the well using said tools and resulting in fractures in said second portion that have a geometry influenced by the rock stress present in said first portion.

25 56. The process of claim 55 wherein said fractures in said second portion extend farther from the well due to influence of the rock stress present in the first portion.

30 57. The process of claim 55 wherein said fractures in said second portion extend farther from the first portion due to influence of the rock stress present in the first portion.

58. The process of claim 55 wherein the well is substantially horizontal through the subterranean environs.

59. The process of claim 55 wherein the subterranean environs is one subterranean formation.

60. The process of claim 55 further comprising:

fracturing a third portion of said subterranean environs at a third location along the well using said tools prior to said fracturing of said second portion, said fracturing of said third portion creating rock stress within said  
5 third portion that influences the geometry of said fractures in said second portion.

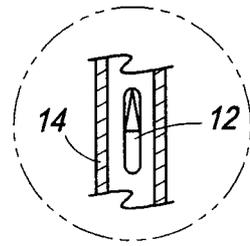
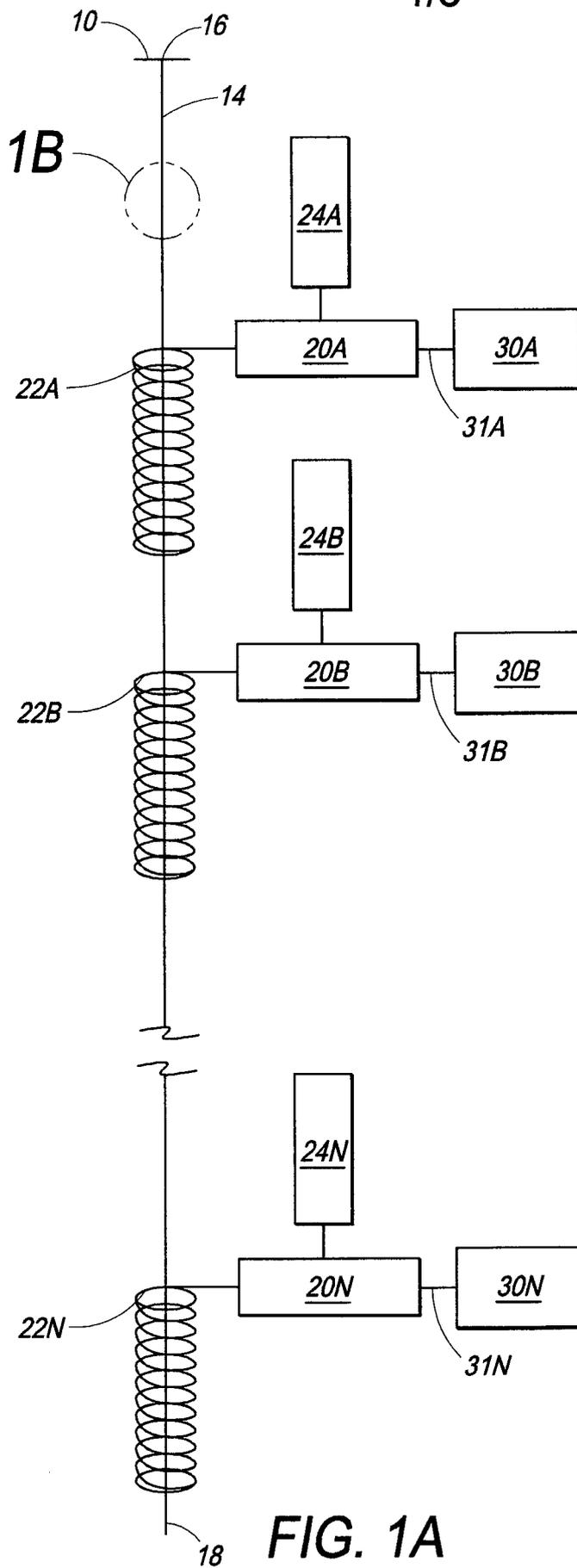


FIG. 1B

FIG. 1A

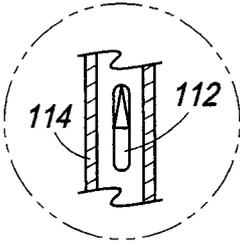


FIG. 2B

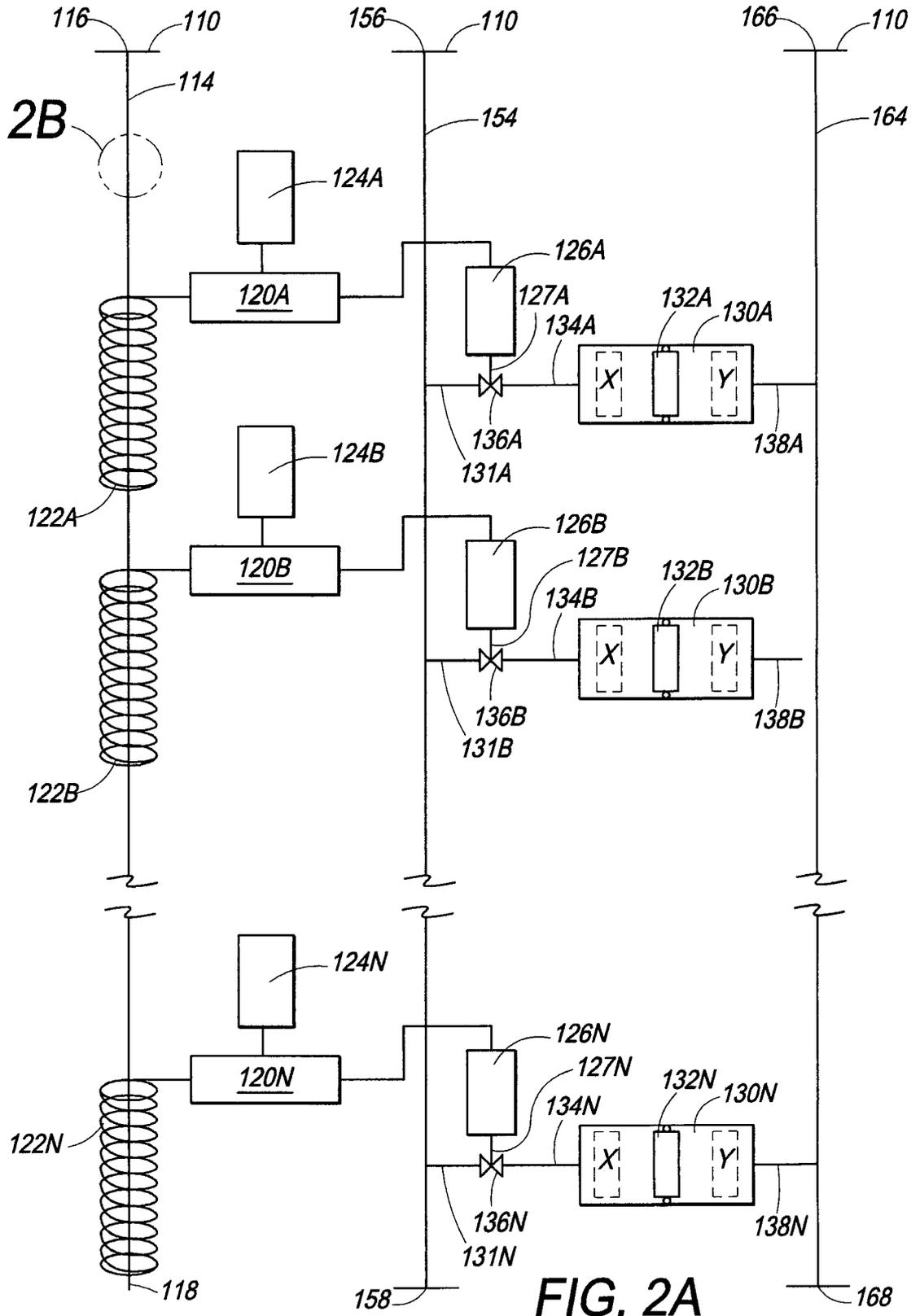


FIG. 2A

FIG. 3B

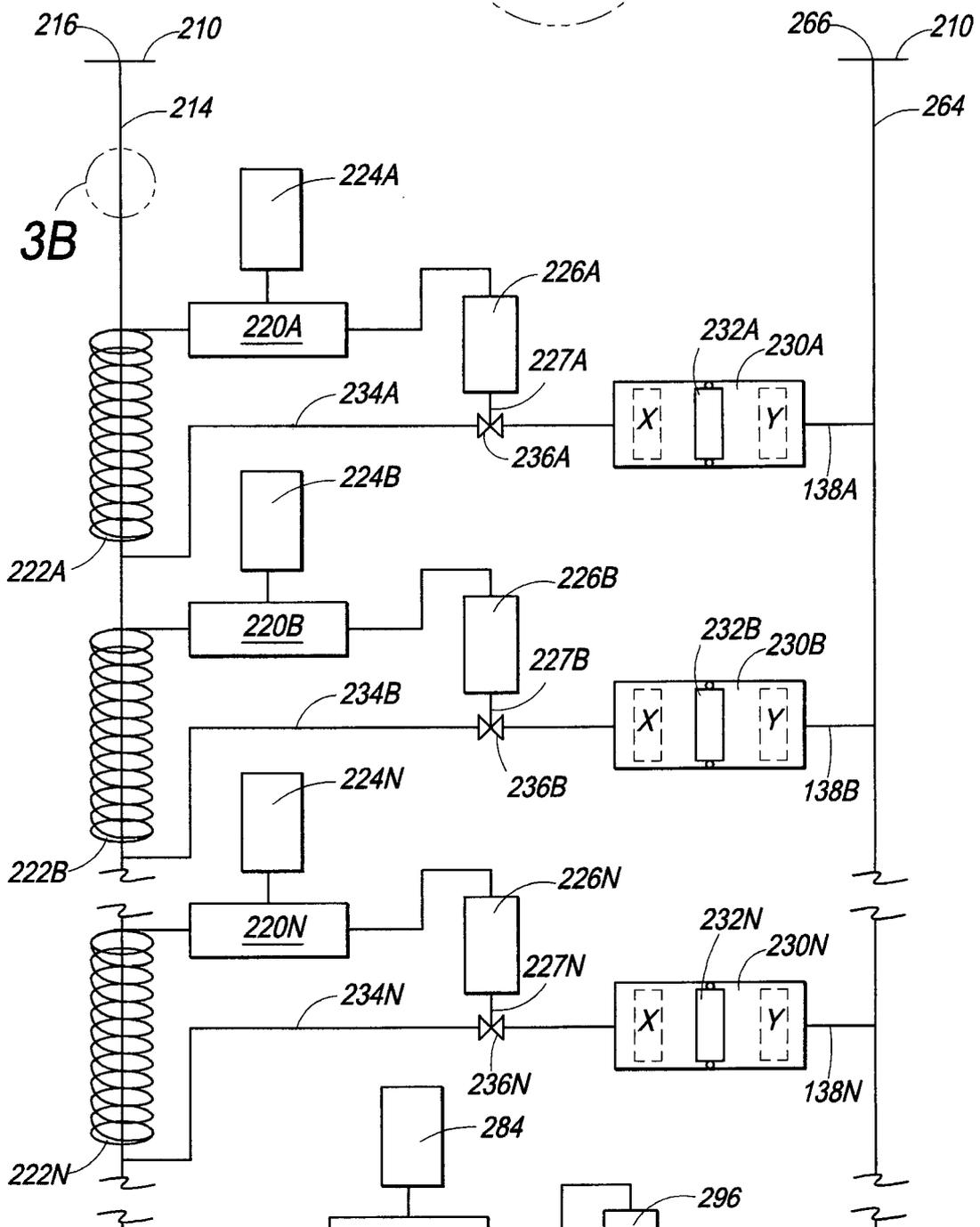
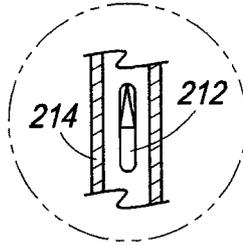
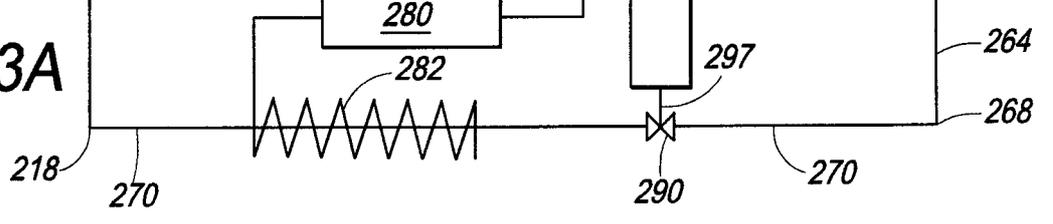
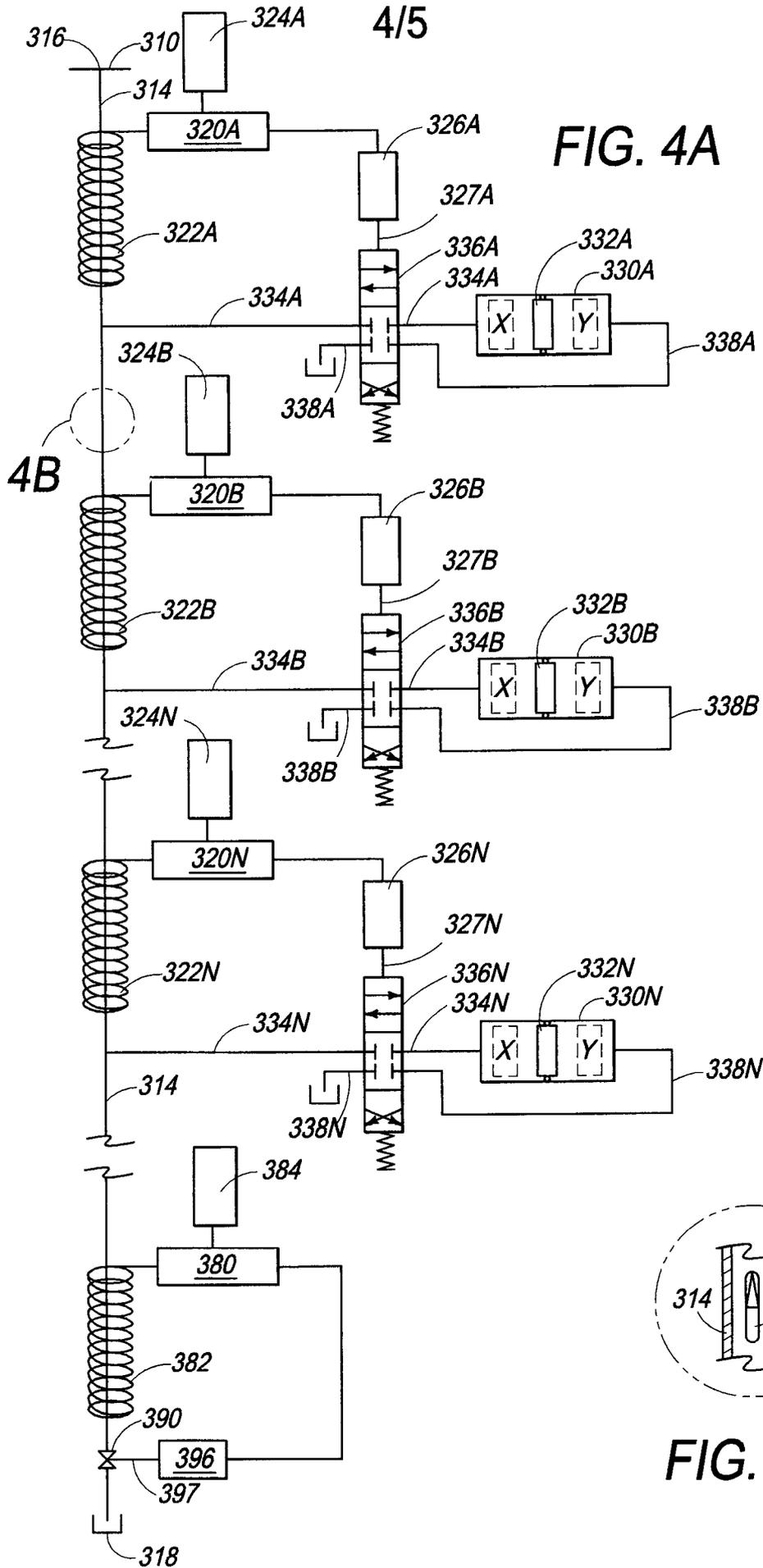


FIG. 3A





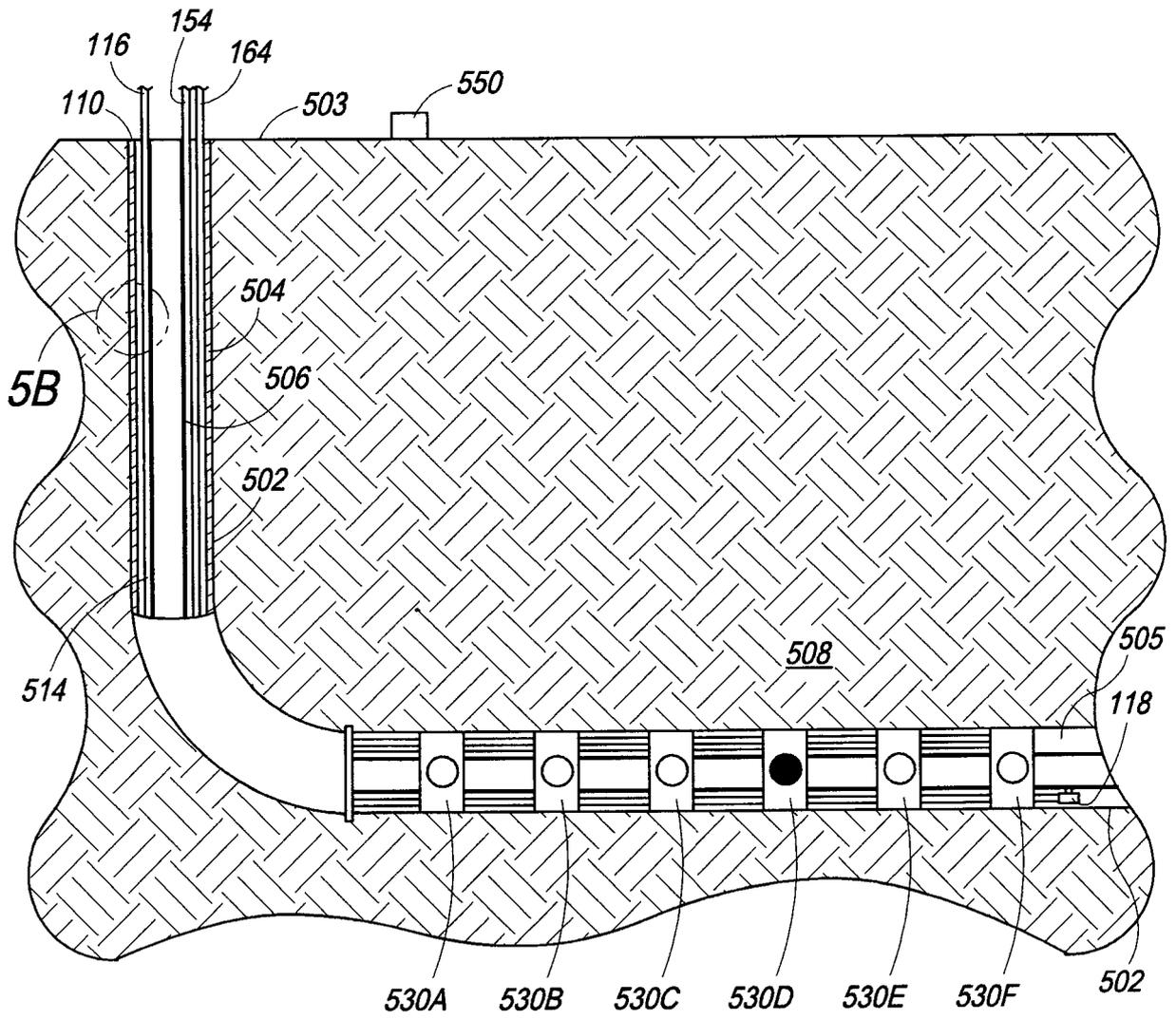


FIG. 5A

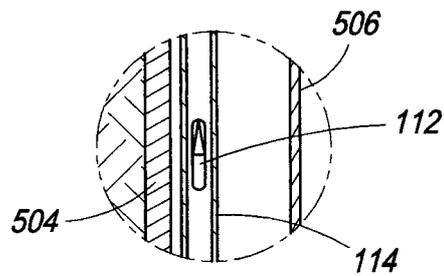


FIG. 5B

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/035991

<b>A CLASSIFICATION OF SUBJECT MATTER</b> IPC(8) - E21 B 23/08, 34/1 4, 43/26 (2009.01 ) <b>USPC - 166/66.6, 308.1, 373</b> According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B FIELDS SEARCHED</b>		
Minimum documentation searched (classification system followed by classification symbols) IPC(8) - E21 B 21/10, 23/08, 34/14, 43/26 (2009 01) USPC - 166/65 1, 66, 66 4-66 7, 308 1-308 6, 373		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Pat Base		
<b>C DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
X -- Y	US 6,536,524 B 1 (SNIDER) 25 March 2003 (25 03 2003) entire document	1-7, 10, 21-26, 33, 34, 36 ----- 8, 9, 11-20, 27-32, 35, 37-40
X -- Y	US 2004/021 1567 A 1 (AUD) 28 October 2004 (28 10 2004) entire document	41, 43-44, 46, 48, 51, 52, 54-57, 59, 60 ----- 42, 45, 47, 49, 50, 53, 58
Y	US 2002/0093431 A 1 (ZIEROLF) 18 July 2002 (18 07 2002) entire document	8, 9
Y	US 4,1 19,146 A (TAYLOR) 10 October 1978 (10 10 1978) entire document	11-20, 27-32, 35, 37-40
Y	US 6,766,703 B 1 (KLUTH et al) 27 July 2004 (27 07 2004) entire document	31, 32, 37, 38
Y	US 2002/0007949 A 1 (TOLMAN et al) 24 January 2002 (24 02 2002) entire document	42, 45, 47, 49, 50, 53, 58
<b>D</b> Further documents are listed in the continuation of Box C <input type="checkbox"/>		
• Special categories of cited documents	"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	
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
"E" earlier application or patent but published on or after the international filing date	"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	
"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)	"&" document member of the same patent family	
"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		
Date of the actual completion of the international search 17 June 2009	Date of mailing of the international search report <b>25 JUN 2009</b>	
Name and mailing address of the ISA/US Mail Stop PCT, Attn ISA/US, Commissioner for Patents P O Box 1450, Alexandria, Virginia 22313-1450 Facsimile No 571-273-3201	Authorized officer Blame R Copenheaver PCT HelpdesK. 571 272-4300 PCT OSP 571 272 7774	

**INTERNATIONAL SEARCH REPORT**

International application No

PCT/US2009/035991

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons

- 1  Claims Nos  
because they relate to subject matter not required to be searched by this Authority, namely
  
- 2  Claims Nos  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically
  
- 3  Claims Nos  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid

Group I, claims 1-40 are drawn to a hydraulic control system  
Group II, claims 41-60 are drawn to a process

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical features of Group I, a control device, and a control line are not present in Group II, and the special technical features of Group II, fracturing a subterranean environs penetrated by a well at spaced apart locations are not present in Group I

Since none of the special technical features of the Group I-II inventions is found in more than one of the inventions, unity is lacking

- 1  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
  
- 2  As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees
  
- 3  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos
  
- 4  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims, it is covered by claims Nos

**Remark on Protest**

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation
- No protest accompanied the payment of additional search fees