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(54) **Title:** SYSTEM AND METHOD FOR ELECTRONICALLY CONTROLLING DOWNHOLE VALVE SYSTEM

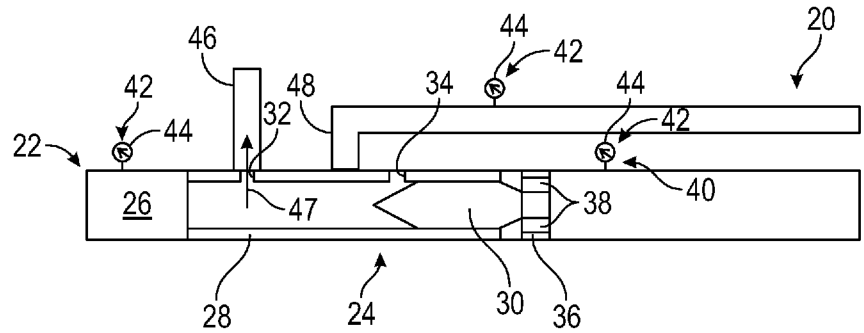

FIG. 1

(57) **Abstract:** A technique facilitates control over packers and/or other well tools actuated downhole. The technique utilizes a valve connectable into a well string. The valve is shiftable between a plurality of modes so as to control flow of fluid in a downhole environment. Additionally, an actuator system is connectable into the well string and operatively coupled with the valve. The actuator system is electronically controlled to cause the valve to shift to a desired mode of the plurality of modes. This approach enables electronic control over the actuation of specific downhole tools, e.g. packers, and/or other well related operations.

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SYSTEM AND METHOD FOR ELECTRONICALLY CONTROLLING DOWNHOLE VALVE SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Non-Provisional Application No. 17/657,523 entitled "System and Method for Electronically Controlling Downhole Valve System," filed March 31, 2022, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

[0001] In many well applications, a well string is deployed downhole into a borehole, e.g. a wellbore. A given well string may comprise packers and other well tools which are actuated downhole. For example, packers may be expanded downhole to establish a seal between the well string and a surrounding wellbore wall, e.g. a surrounding well casing. Traditional methods for actuating downhole packers and other well tools often included dropping a ball from the surface down to a ball seat associated with a given packer/well tool. Appropriate pressure may then be applied down through the well string to cause well tool actuation. For example, pressure can be applied to the dropped ball to shift a valve which, in turn, would direct fluid flow to inflate or otherwise actuate a packer. Other types of downhole actuation rely on complex mechanical valves operated via pumping pressure or involve mechanically pushing or pulling on well tubing, e.g. coiled tubing, to achieve the desired downhole well tool actuation. However, such methods tend to be complex and time-consuming.

SUMMARY

[0002] In general, a system and methodology facilitate control over packers and/or other well tools actuated downhole. The technique utilizes a valve connectable into a well string. The valve is shiftable between a plurality of modes so as to control

flow of fluid in a downhole environment. Additionally, an actuator system is connectable into the well string and operatively coupled with the valve. The actuator system is electronically controlled to cause the valve to shift to a desired mode of the plurality of modes. This approach enables electronic control over the actuation of specific downhole tools, e.g. packers, and/or other well related operations.

[0003] However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] 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 figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0005] Figure 1 is a schematic illustration of an example of a well system having a valve deployed along a well string, according to an embodiment of the disclosure;

[0006] Figure 2 is a schematic illustration of the well system illustrated in Figure 1 but showing the valve in a different operational position, according to an embodiment of the disclosure;

[0007] Figure 3 is a schematic illustration of the well system illustrated in Figure 2 but showing the valve in the different operational position, according to an embodiment of the disclosure;

[0008] Figure 4 is a schematic illustration of a well system having a well string deployed via coiled tubing and comprising the valve in a first operational position, according to an embodiment of the disclosure;

[0009] Figure 5 is a cross-sectional illustration of an example of the valve illustrated in Figure 4, according to an embodiment of the disclosure;

[0010] Figure 6 is a schematic illustration of an example of the valve illustrated in Figure 4, according to an embodiment of the disclosure;

[0011] Figure 7 is a schematic illustration of a well system having a well string deployed via coiled tubing and comprising the valve in a second operational position, according to an embodiment of the disclosure;

[0012] Figure 8 is a cross-sectional illustration of an example of the valve illustrated in Figure 7, according to an embodiment of the disclosure;

[0013] Figure 9 is a schematic illustration of an example of the valve illustrated in Figure 7, according to an embodiment of the disclosure;

[0014] Figure 10 is a schematic illustration of a well system having a well string deployed via coiled tubing and comprising the valve in a third operational position, according to an embodiment of the disclosure;

[0015] Figure 11 is a cross-sectional illustration of an example of the valve illustrated in Figure 10, according to an embodiment of the disclosure;

[0016] Figure 12 is a schematic illustration of an example of the valve illustrated in Figure 10, according to an embodiment of the disclosure; and

[0017] Figure 13 is a schematic illustration of a well system having a valve which is electronically controlled via an electronically controlled actuator system, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0018] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0019] The disclosure herein generally involves a system and methodology facilitate control over packers and/or other well tools actuated downhole. The technique utilizes a valve connectable into a well string. The valve is shiftable between a plurality of modes so as to control flow of fluid in a downhole environment. By way of example, the valve may be selectively controlled via electronic input to provide appropriate modes for deploying and actuating inflatable packer elements in a well. The valve may be used to inflate a single packer element or to inflate a plurality of packer elements, e.g. a set of straddle packers used to isolate a treatment zone. In some embodiments, the valve may be selectively actuated to a mode which enables pumping of treatment fluid into the straddled zone.

[0020] An actuator system may be connected into the well string and operatively coupled with the valve. The actuator system is electronically controlled to cause the valve to shift to a desired mode of the plurality of modes. This approach enables electronic control over the actuation of specific downhole tools, e.g. packers, and/or other well related operations. By way of example, the actuator system may be used to shift the valve between three modes or operational positions in which fluid is directed out to the annulus above the packers for recirculation; into the packers for inflation; or below/between the packers for a treatment injection. The overall valve system also may be instrumented to monitor valve actuation, e.g. to monitor pressures in the different areas where the fluid is being pumped and/or trapped. The use of pressure monitoring enables precise observation of differential pressures to ensure, for example, integrity of the packers.

[0021] Referring generally to Figure 1, an example of a well system 20 is illustrated as deployed along a well string 22. Well system 20 comprises a valve 24 shiftable between a plurality of operational positions to control fluid flows directed along an interior 26 of the well string 22. By way of example, the valve 24 may comprise an outer piston 28 which is selectively movable/shiftable with respect to an inner piston sealing structure 30 so as to achieve different valve positions and thus different operational modes.

[0022] According to an embodiment, the piston 28 may be tubular in shape and comprise a plurality of lateral openings, e.g. lateral openings 32 and 34. The inner piston sealing structure 30 is sized and shaped to enable sealing engagement with an interior surface of the piston 28. Depending on the configuration of well string 22 and valve 24, the inner piston sealing structure 30 may be secured via a mounting structure 36 having flow passages 38. By way of example, the mounting structure 36 may be secured within an outer valve housing or within a corresponding tubular structure of the well string 22.

[0023] A sensor system 40 also may be incorporated into the well string 22 and may comprise a plurality of sensors 42. In some embodiments, the sensors 42 may comprise pressure sensors 44 positioned at different locations with respect to valve 24 so as to monitor pressures and differential pressures of, for example, fluid being pumped and/or fluid trapped at specific areas.

[0024] Depending on the specific application, the valve 24 may be constructed as shiftable between modes which include a circulation mode, a packer inflation mode, and a treatment mode. Referring to Figure 1, for example, the valve 24 is illustrated as a three way valve positioned in the circulation mode. In this mode, valve 24 is shifted such that tubular piston 28 is engaged with inner piston sealing structure 30 so as to prevent fluid from flowing past structure 30. Additionally, lateral opening 34 is misaligned while lateral opening 32 is aligned with circulation passage 46, thus enabling circulation of fluid down through well string 22, out through lateral opening 32/passage 46 (see arrow 47), and then back up through an annulus between well string 22 and a surrounding wellbore wall.

[0025] By shifting the outer piston 28 longitudinally, as illustrated in Figure 2, the valve 24 is shifted to a packer inflation mode. In this configuration, outer piston 28 remains engaged with inner piston sealing structure 30. However, lateral opening 32 becomes misaligned while lateral opening 34 is aligned with a packer inflation passage 48. This enables circulation of fluid down through well string 22, out through lateral opening 34/inflation passage 48, and to a packer or packers (not shown) to inflate the packer(s) into sealing engagement with the surrounding wellbore wall (see arrows 49).

[0026] By further shifting the outer piston 28 longitudinally, as illustrated in Figure 3, the valve 24 is shifted to a well treatment mode. In this configuration, outer piston 28 disengages from inner piston sealing structure 30 so as to allow treatment fluid to flow past the inner piston sealing structure 30 (see arrows 50) for subsequent injection into the surrounding formation. In the well treatment mode, both lateral opening 32 and lateral opening 34 become misaligned to block lateral fluid flow and to thus ensure the treatment fluid flows downhole past valve 24.

[0027] Referring generally to Figure 4, an embodiment of well system 20 is illustrated in which well string 22 is deployed in a wellbore 52 or other type of borehole drilled into a surrounding formation 54. In this example, the well string 22 comprises a plurality of packers 56, e.g. two packers arranged in a straddle packer configuration as illustrated. Along with packers 56, the well string 22 comprises valve 24 which is controlled via an electronically controlled actuation system 58. The actuation system 58 may be positioned along well string 22 adjacent valve 24 or at another suitable location.

[0028] The actuation system 58 responds to electric control signals provided via controller 60. Controller 60 may receive commands from the surface and/or may be programmed to provide certain control commands to actuation system 58, and thus valve 24. For example, controller 60 may be programmed to respond according to parameters sensed downhole via, for example, sensor system 40. The controller 60 is illustrated as located downhole along well string 22, however the controller 60 also can be located at the surface or at other locations along the well string.

[0029] In this example, the packers 56 and other well equipment of well string 22 are deployed downhole via tubing 62. In a variety of applications, the tubing 62 may be in the form of coiled tubing 64.

[0030] In Figure 4, the valve 24 is positioned in the circulation mode, as further illustrated by Figures 5 and 6. In this embodiment, the tubular outer piston 28 comprises a plurality of piston components 66 which slide within a surrounding valve housing 68. Appropriate seals 70 may be positioned about the outer piston 28. The inner piston sealing structure 30 is affixed to the surrounding valve housing 68 via mounting structure 36. In this example, lateral opening 32 comprises a plurality of lateral openings and lateral opening 34 similarly comprises a plurality of lateral openings.

[0031] In the circulation mode, valve 24 is shifted such that tubular piston 28 is engaged with inner piston sealing structure 30 so as to prevent fluid from flowing past structure 30. Additionally, lateral openings 34 are misaligned while lateral openings 32 are aligned with corresponding circulation passages 46, thus enabling circulation of fluid down through well string 22, e.g. down through coiled tubing 64, out through lateral openings 32/passages 46 (see arrows 47 in Figure 6), and then along an annulus 72 between well string 22 and a surrounding wellbore wall 74 of wellbore 52 (see Figure 4). The pressure sensors 44 (or other suitable sensors) may be used to monitor pressures on each side of piston 28 and to provide this differential pressure feedback to controller 60 and/or to a surface control system to enable monitoring of the position of valve 24.

[0032] It should be noted the packers 56 are illustrated as inflated against the surrounding wellbore wall 74, however the circulation mode may be utilized prior to expansion of packers 56. The packers 56 would then be subsequently expanded by shifting valve 24 to the packer inflation mode illustrated in Figures 7-9.

[0033] In the packer inflation mode, outer piston 28 remains engaged with inner piston sealing structure 30. However, lateral openings 32 become misaligned while lateral openings 34 are aligned with corresponding packer inflation passages 48. This enables circulation of fluid down through well string 22, e.g. down through coiled tubing 64, out through lateral openings 34/inflation passages 48, and to packers 56 to inflate the packers 56 into sealing engagement with the surrounding wellbore wall 74 (see arrows 49). Again, pressure sensors 44 (or other suitable sensors) may be used to monitor pressures on each side of piston 28 and to provide this differential pressure feedback to controller 60 and/or to a surface control system to enable monitoring of the position of valve 24.

[0034] It should be noted valve 24 also enables the use of a broader range of packer elements. Traditional packer setting tools employ some type of anchor to allow activation by pushing or pulling against that anchor to achieve the desired shifting between flow positions. By utilizing the electronically controlled valve 24, the anchoring requirement may be eliminated. This approach enables on-demand shifting of valve 24 without anchoring and allows use of the system described herein with a wider range of packers and in a wider range of environments.

[0035] Once packers 56 have been inflated, the valve 24 may be shifted to the well treatment mode illustrated in Figures 10-12. In this mode, outer piston 28 disengages from inner piston sealing structure 30 so as to allow treatment fluid to flow past the inner piston sealing structure 30 (see arrows 50) for subsequent injection into the surrounding formation. In the well treatment mode, both lateral openings 32 and lateral openings 34 become misaligned to block lateral fluid flow and to thus ensure the treatment fluid flows downhole past valve 24.

[0036] By way of example, the well treatment fluid 50 may be directed down through well string 22 past valve 24 to a position between the two packers 56 for injection into the surrounding formation 54 as indicated by arrow 76 in Figure 10. Similar to the monitoring performed in other modes, pressure sensors 44 (or other suitable sensors) may be used to monitor pressures on each side of piston 28 and to provide this differential pressure feedback to controller 60 and/or to a surface control system to enable monitoring of the position of valve 24. It should be noted that valve 24 has been described as a three position valve, however other types of valves with other numbers of valve positions may be used to accomplish the desired transitioning between modes.

[0037] Additionally, the operation of valve 24, the number and type of modes, and the sequence of actuation may change to accommodate the parameters of a given downhole operation. In many applications, however, the ability to provide electronic control over the actuation of valve 24 greatly simplifies transitioning between operational modes while reducing the time associated with such transitions as compared to, for example, traditional use of a dropped ball to enable shifting of a piston or valve between operational modes.

[0038] One approach for providing such electronic control is illustrated in Figure 13. In this example, the electronically controlled actuation system 58 comprises a motor 78 which may be operated according to electrical commands received from controller 60. For example, the motor 78 may be started or stopped in a clockwise direction or a counterclockwise direction. This motion, in turn, is imparted to a bidirectional pump 80 which may have suitable integrated filters and valves. In some embodiments, the pump 80 also may be fluidly coupled with a compensator 82 via a flow line 84 and a filter 86.

[0039] The pump 80 also is in operative engagement with valve 24. As illustrated, the pump 80 may be in fluid communication with piston 28 via hydraulic actuation fluid lines 88. For example, one of the fluid lines 88 may be connected to deliver hydraulic actuation fluid to one side of piston 28 while the other hydraulic fluid line 88 is connected to deliver hydraulic actuation fluid to the opposite side of piston 28 so as to enable controlled longitudinal shifting of piston 28 as described above. The hydraulic actuation fluid may be contained downhole or delivered downhole via a suitable flow line. Appropriate pressure sensors 44 and/or other sensors may be positioned along fluid lines 88 so as to monitor the pressure differential between sides of piston 28, thus providing feedback as to the operation of valve 24.

[0040] By providing the appropriate electronic control signals to motor 78, the pump 80 may be operated in one direction to drive piston 28 longitudinally in a first direction. Similarly, appropriate electronic control signals may be provided to motor 78 to cause pump to be operated in the opposite direction, thus driving piston 28 in a second or opposite direction. As a result, the valve 24 may be shifted between operational modes based on the electronic control signals provided.

[0041] Depending on the downhole application, the valve 24 may comprise a single valve or a plurality of valves. Additionally, the valve 24 may be configured to provide a variety of desired operational modes to achieve appropriate downhole tool operation and/or downhole fluid flows. The actuation system 58 may comprise various components, e.g. various motors and pumps, to control shifting of piston 28. Similarly, controller 60 may comprise a variety of computer programmable controllers or other suitable controllers able to receive command inputs and to provide appropriate control signals to actuation system 58/valve 24. The sensors 42 may comprise pressure sensors, position sensors, and/or other sensors selected to provide feedback on valve position and corresponding mode. The electrically controlled valve system may be used with many types of well strings in a variety of well applications.

[0042] In certain embodiments of the present disclosure, a system for use in a well includes a well string sized for deployment in a borehole. The well string includes coiled tubing, a first packer and a second packer deployable to a desired location in the borehole via the coiled tubing, and a valve shiftable between modes. The modes include a circulation mode, a packer inflation mode, and a treatment mode. The valve is shiftable between the modes via electronic control. The well string also includes a sensor system having sensors positioned along the well string to provide data indicative of the mode of the valve.

[0043] In some embodiments, the valve includes an outer piston movable with respect to an inner piston sealing structure. In some embodiments, the sensors comprise pressure sensors. In some embodiments, the electronic control includes an electronically controlled actuation system which controls delivery of hydraulic actuating fluid to the valve to enable shifting of the valve between the modes. In some embodiments, the electronically controlled actuation system comprises a downhole electric motor coupled to a pump for delivering the hydraulic actuating fluid.

[0044] In some embodiments, when the valve is positioned in the circulation mode, the valve allows fluid to be directed down through the coiled tubing, through the valve, and out into an annulus between the coiled tubing and a surrounding wall of the borehole. In some embodiments, when the valve is positioned in the packer inflation mode, the valve enables fluid to be directed down through the coiled tubing and to the first packer and the second packer to inflate the first packer and the second packer. In some embodiments, when the valve is positioned in the treatment mode, the valve enables fluid to be directed down through the valve and into a surrounding formation. In some embodiments, when the valve is positioned in the treatment mode, the valve enables fluid to be directed down through the valve, outwardly between the first packer and the second packer, and into the surrounding formation.

[0045] In certain embodiments of the present disclosure, a system includes a valve connectable into a well string and an actuation system connectable into the well string and operatively coupled with the valve. The valve is shiftable between a plurality of modes to control flow of fluid in a downhole environment. The actuation system is electronically controlled to cause the valve to shift to a desired mode of the plurality of modes.

[0046] In some embodiments, the system includes a packer selectively inflatable via fluid flow controlled by the valve. In some embodiments, the system includes a first packer and a second packer selectively inflatable without anchoring. The first and second packers are inflatable via fluid flow controlled by the valve. In some embodiments, the plurality of modes include a circulation mode, a packer inflation mode, and a treatment mode. In some embodiments, the system includes a sensor system having sensors positioned along the well string to provide data indicative of the mode of the valve. In some embodiments, the sensors include pressure sensors. In some embodiments, when the valve is positioned in the treatment mode, the valve enables fluid to be directed down through the well string, outwardly between the first packer and the second packer, and into the surrounding formation.

[0047] In certain embodiments of the present disclosure, a method includes positioning an inflatable packer along a well string sized for deployment in a wellbore, connecting a valve along the well string to selectively enable flow of fluid to the inflatable packer during inflation of the packer, providing the valve with additional valve positions for controlling flows of fluid in the wellbore, and using an electronically controlled downhole actuation system to cause actuation of the valve between valve positions.

[0048] In some embodiments, positioning includes positioning both the inflatable packer and an additional inflatable packer along the well string. The valve controlling flow of fluid to inflate both the inflatable packer and the additional inflatable packer. In some embodiments, the method includes actuating the valve to a well treatment mode to enable flow of a well treatment fluid through the valve and performing a well treatment. In some embodiments, the method includes constructing the valve as a three way valve. Constructing the valve includes constructing the valve with an outer piston movable with respect to an inner piston sealing structure.

[0049] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

What is claimed is:

1. A system for use in a well, comprising:

a well string sized for deployment in a borehole, the well string comprising:

coiled tubing;

a first packer and a second packer deployable to a desired location in the borehole via the coiled tubing;

a valve shiftable between modes, the modes including a circulation mode, a packer inflation mode, and a treatment mode, the valve being shiftable between the modes via electronic control; and

a sensor system having sensors positioned along the well string to provide data indicative of the mode of the valve.

2. The system as recited in claim 1, wherein the valve comprises an outer piston movable with respect to an inner piston sealing structure.

3. The system as recited in claim 1, wherein the sensors comprise pressure sensors.

4. The system as recited in claim 1, wherein the electronic control comprises an electronically controlled actuation system which controls delivery of hydraulic actuating fluid to the valve to enable shifting of the valve between the modes.

5. The system as recited in claim 4, wherein the electronically controlled actuation system comprises a downhole electric motor coupled to a pump for delivering the hydraulic actuating fluid.

6. The system as recited in claim 1, wherein when the valve is positioned in the circulation mode, the valve allows fluid to be directed down through the coiled

tubing, through the valve, and out into an annulus between the coiled tubing and a surrounding wall of the borehole.

7. The system as recited in claim 1, wherein when the valve is positioned in the packer inflation mode, the valve enables fluid to be directed down through the coiled tubing and to the first packer and the second packer to inflate the first packer and the second packer.

8. The system as recited in claim 1, wherein when the valve is positioned in the treatment mode, the valve enables fluid to be directed down through the valve and into a surrounding formation.

9. The system as recited in claim 1, wherein when the valve is positioned in the treatment mode, the valve enables fluid to be directed down through the valve, outwardly between the first packer and the second packer, and into the surrounding formation.

10. A system, comprising:

a valve connectable into a well string, the valve being shiftable between a plurality of modes to control flow of fluid in a downhole environment; and

an actuation system connectable into the well string and operatively coupled with the valve, the actuation system being electronically controlled to cause the valve to shift to a desired mode of the plurality of modes.

11. The system as recited in claim 10, further comprising a packer selectively inflatable via fluid flow controlled by the valve.

12. The system as recited in claim 10, further comprising a first packer and a second packer selectively inflatable without anchoring, the first and second packers being inflatable via fluid flow controlled by the valve.

13. The system as recited in claim 12, wherein the plurality of modes comprises a circulation mode, a packer inflation mode, and a treatment mode.

14. The system as recited in claim 13, further comprising a sensor system having sensors positioned along the well string to provide data indicative of the mode of the valve.

15. The system as recited in claim 14, wherein the sensors comprise pressure sensors.

16. The system as recited in claim 13, wherein when the valve is positioned in the treatment mode, the valve enables fluid to be directed down through the well string, outwardly between the first packer and the second packer, and into the surrounding formation.

17. A method, comprising:

positioning an inflatable packer along a well string sized for deployment in a wellbore;

connecting a valve along the well string to selectively enable flow of fluid to the inflatable packer during inflation of the packer;

providing the valve with additional valve positions for controlling flows of fluid in the wellbore; and

using an electronically controlled downhole actuation system to cause actuation of the valve between valve positions.

18. The method as recited in claim 17, wherein positioning comprises positioning both the inflatable packer and an additional inflatable packer along the well string, the valve controlling flow of fluid to inflate both the inflatable packer and the additional inflatable packer.

19. The method as recited in claim 17, further comprising actuating the valve to a well treatment mode to enable flow of a well treatment fluid through the valve; and performing a well treatment.

20. The method as recited in claim 17, further comprising constructing the valve as a three way valve, wherein constructing the valve comprises constructing the valve with an outer piston movable with respect to an inner piston sealing structure.

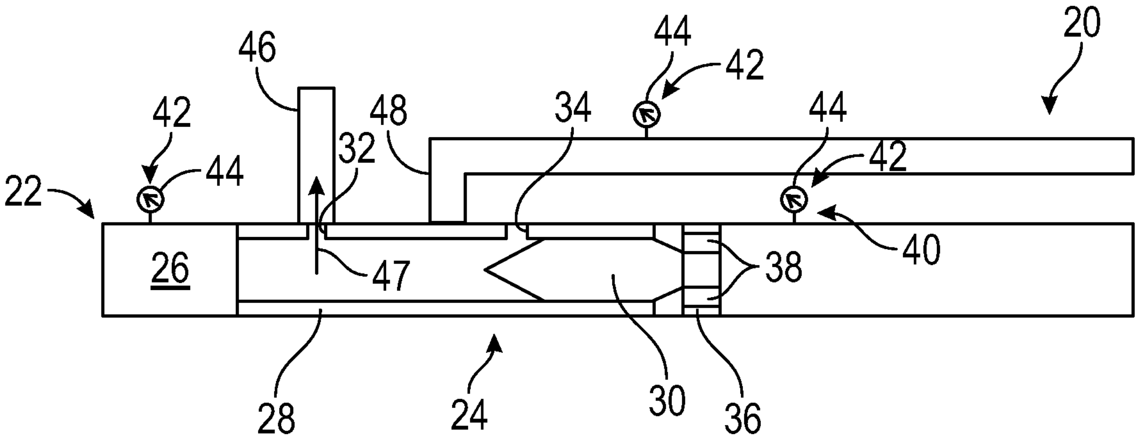

FIG. 1

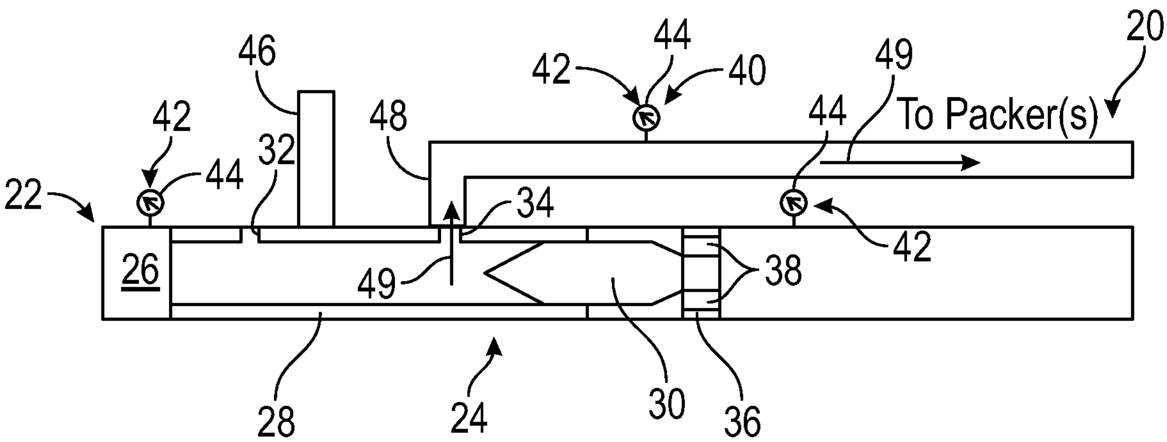

FIG. 2

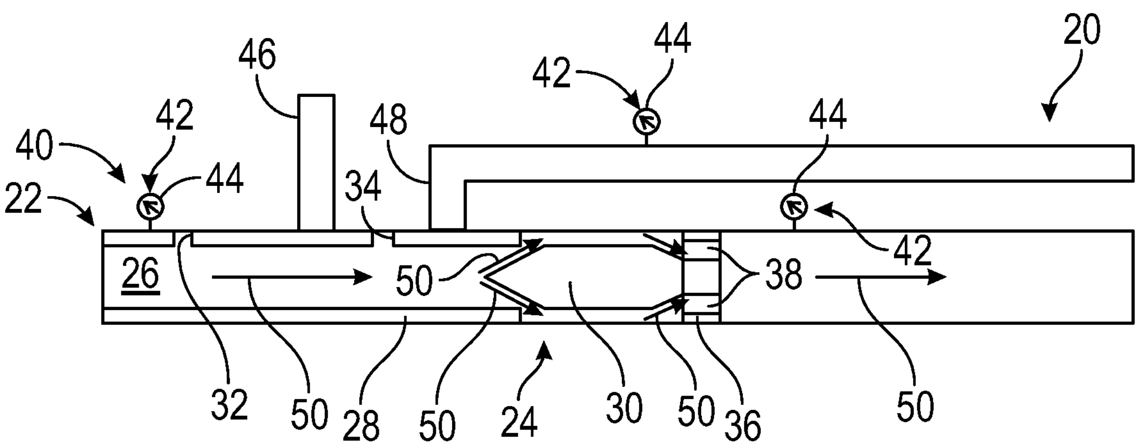

FIG. 3

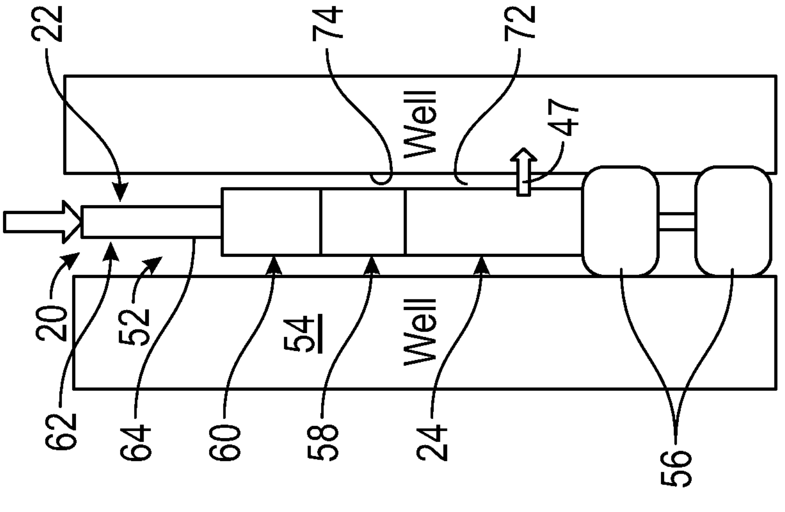
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FIG. 4

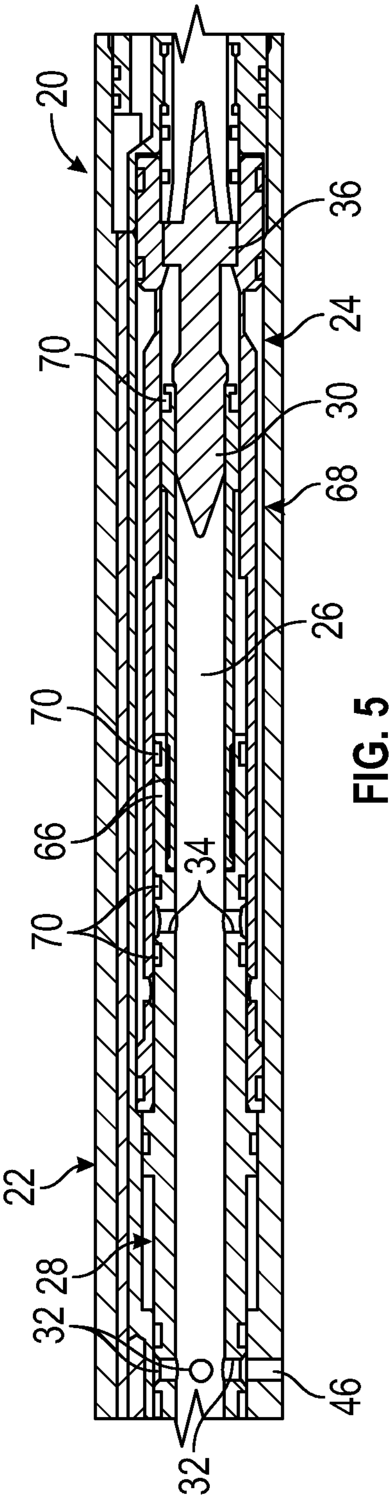
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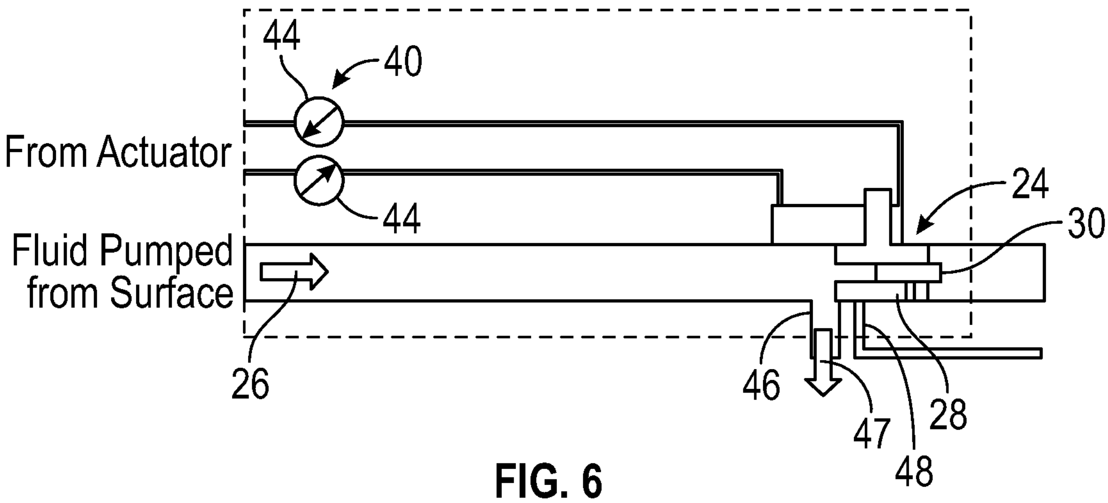
FIG. 5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28
48

FIG. 6

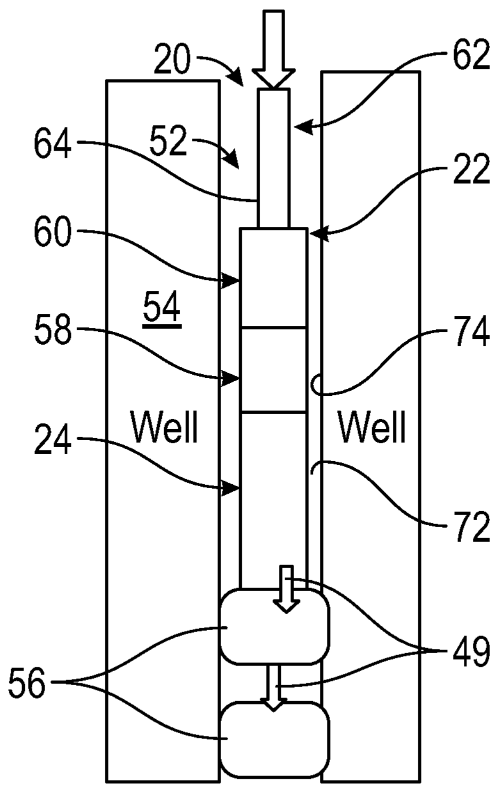

20
62
64
52
22
60
54
58
74
24
Well
Well
72
49
56

FIG. 7

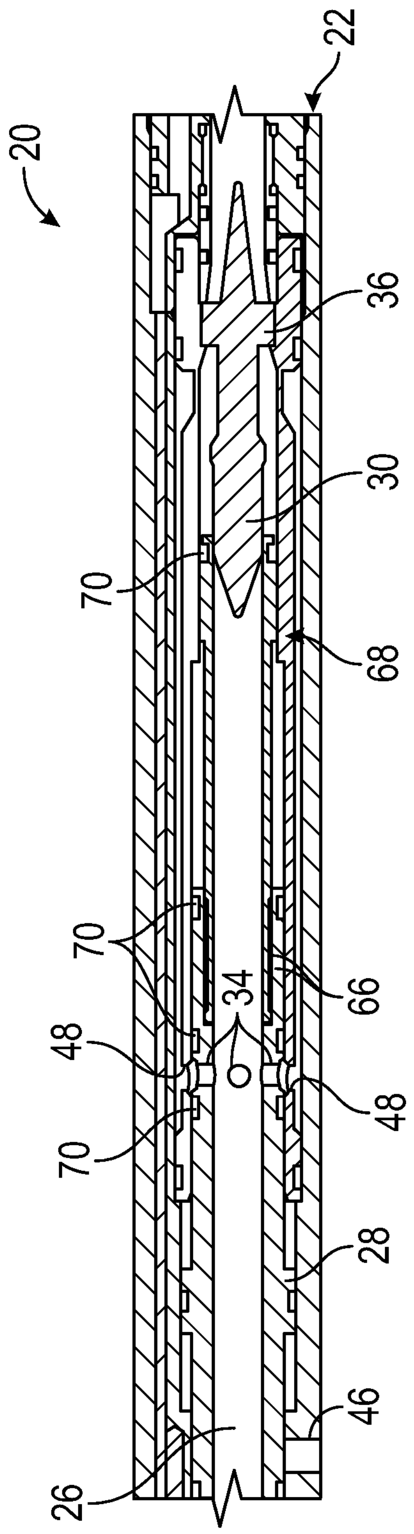

20
22
36
30
70
68
70
34
66
48
48
70
28
46
26

FIG. 8

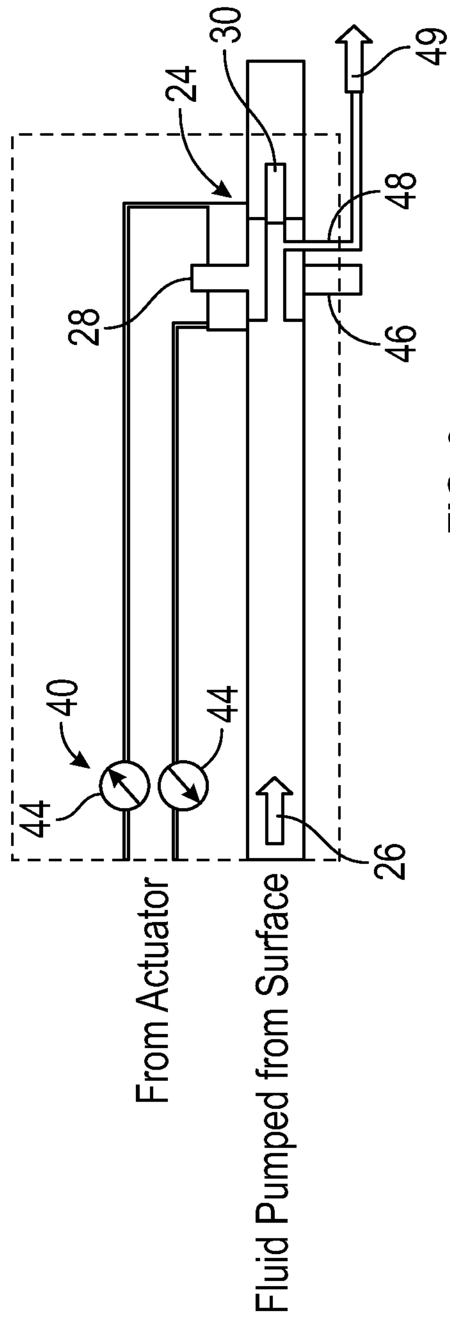

30
49
24
48
28
46
40
44
44
26
From Actuator
Fluid Pumped from Surface

FIG. 9

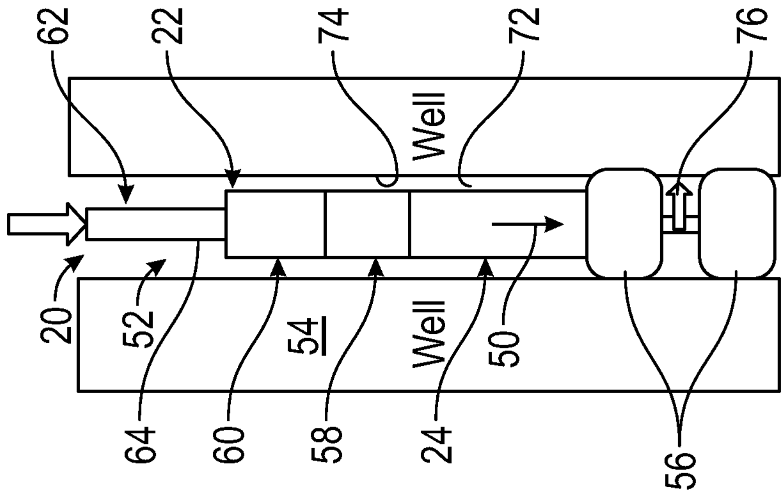
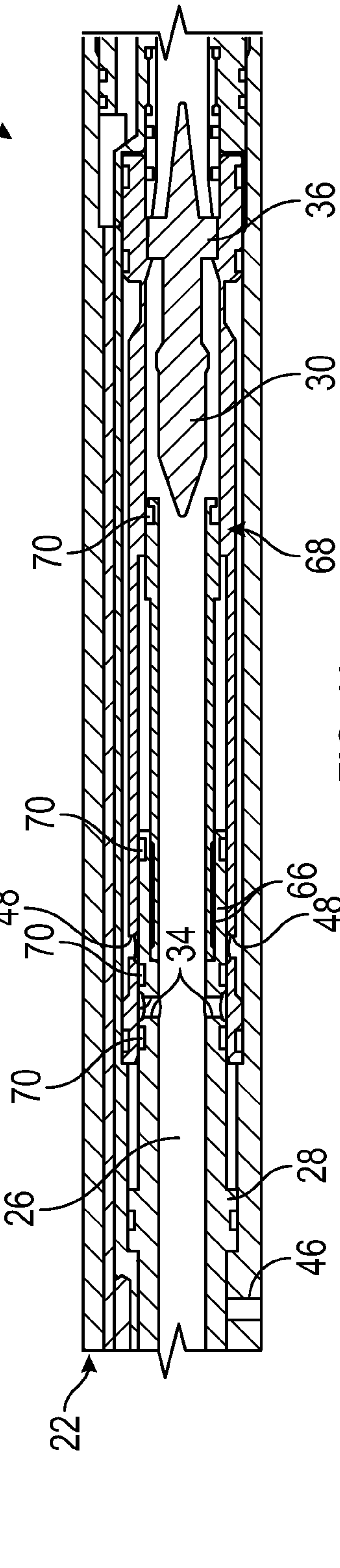

62
22
74
72
76
Well
Well
54
20
52
50
64
60
58
24
56

FIG. 10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36
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68
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48
70
66
48
34
70
26
28
46
22

FIG. 11

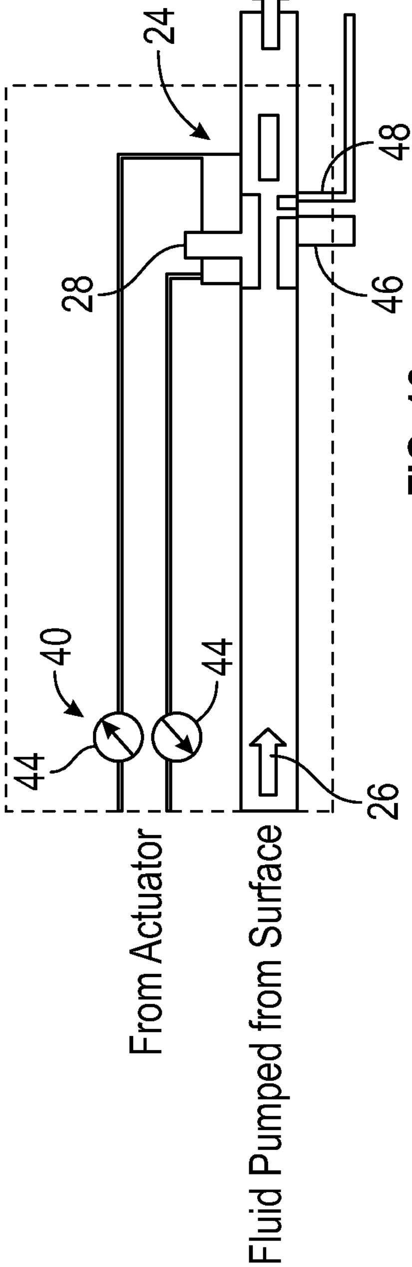
From Actuator
Fluid Pumped from Surface
24
48
28
46
40
44
44
26

FIG. 12

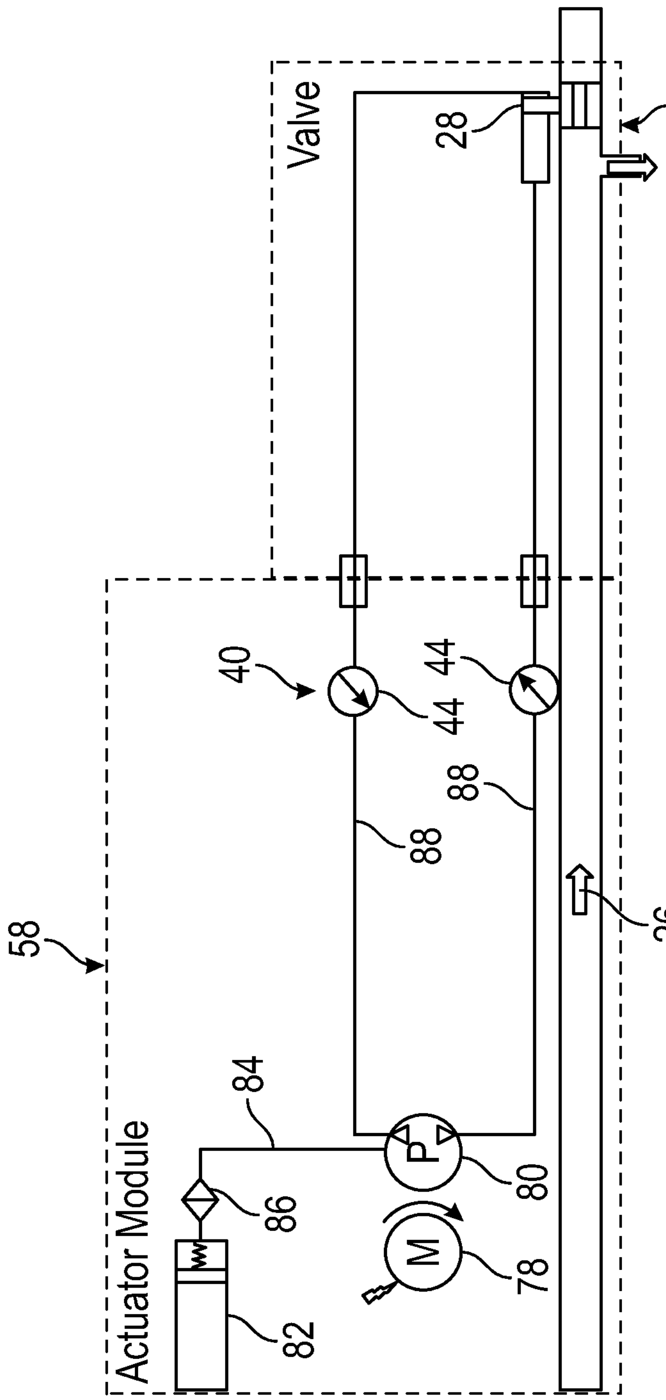
Valve
28
24
40
44
44
88
88
26
58
Actuator Module
84
86
P
80
M
78
82

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/017018

A. CLASSIFICATION OF SUBJECT MATTER

E21B 34/06(2006.01)i; **E21B 33/127**(2006.01)i; **E21B 47/06**(2006.01)i; **E21B 43/12**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 34/06(2006.01); E21B 34/04(2006.01); E21B 34/10(2006.01); E21B 34/16(2006.01); E21B 47/00(2006.01); E21B 47/06(2006.01); E21B 49/08(2006.01)

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

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: well, string, valve, three modes, packer, circulation, treatment, electronic control, motor, pump

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4913231 A (MULLER et al.) 03 April 1990 (1990-04-03) column 4, lines 4-32, column 5, lines 22-38, column 9, lines 17-53 and figures 1, 9, 10, 11, 12	1-20
Y	EP 2281105 B1 (VETCO GRAY SCANDINAVIA AS.) 12 December 2018 (2018-12-12) paragraphs [0040], [0041], [0043], [0065] and figures 1, 2, 10	1-20
A	US 2020-0115992 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 16 April 2020 (2020-04-16) paragraphs [0026]-[0048] and figures 1-5	1-20
A	CN 206458407 U (PETROCHINA COMPANY LIMITED) 01 September 2017 (2017-09-01) paragraphs [0046]-[0050] and figures 1, 2	1-20
A	WO 2022-016023 A2 (MOHAWK ENERGY LTD.) 20 January 2022 (2022-01-20) paragraph [0014] and figures 1, 2	1-20

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

* Special categories of cited documents:
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"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 July 2023	**28 July 2023**

Name and mailing address of the ISA/KR	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2023/017018

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				US	2023-0167835	A1	01 June 2023
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