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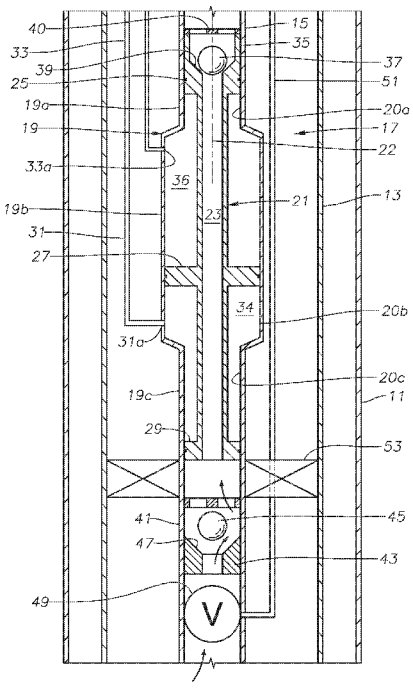

FIG. 1

(57) Abstract: A downhole well pump (17) has a housing (19) with a housing bore having an upper section (20a), a lower section (20c) and an intermediate section (20b) with a larger inner diameter. A plunger (21) has an upper plunger portion (25) in the upper section of the housing bore, a piston (27) in the intermediate section of the housing bore, and a lower plunger portion (29) in the lower section of the housing bore. A hydraulic pump (55) at the surface alternately supplies hydraulic fluid pressure to the upper and lower sides of the piston to cause the plunger to move upward and downward. A standing valve (43) in the housing admits well fluid into the housing during the lifting stroke. A travelling valve (35) moves in unison with the plunger for discharging well fluid from the housing during the lifting stroke.

WO 2020/163232 A1

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DOUBLE HYDRAULIC ACTIVATED RECEPTACLE PUMP

Field of Disclosure

[0001] This disclosure relates to reciprocating well pumps, and in particular to a downhole pump having a plunger with a piston that is driven between a lifting and retracting stroke by hydraulic pressure alternately supplied to opposite sides of the piston.

Background

[0002] A variety of pumps are used in oil producing wells to pump well fluid to a wellhead assembly at an upper end of the well. The well fluid often comprises water and oil and gas. Typical pumps include rotary pumps, such as centrifugal or progressing cavity types, or they may be reciprocal pumps having a plunger that strokes upward and downward within a polished bore of a barrel or housing. The pump may be electrically driven by a downhole motor or, in the case of reciprocal pumps, stroked by a string of rods extending downward from the wellhead assembly.

[0003] Rod driven reciprocal pumps have concerns, such as rod tubing wear and system lower efficiency due to the extension and retraction of the rod string. Also surface environmental problems may occur at the stuffing box of the wellhead assembly.

[0004] Reciprocal pumps powered by a surface hydraulic pump are also known. Hydraulic pump systems have a variety of designs, but improvements are desirable.

Summary

[0005] An apparatus for pumping well fluid from a well, comprises a housing for securing to a string of tubing, the housing having a housing bore with an upper section, a lower section and an intermediate section between the upper and lower sections, the intermediate section having a larger inner diameter than inner diameters of the upper and lower sections. A plunger is carried reciprocally in the housing between a lifting stroke and a retracting stroke, the plunger having an upper plunger portion in sliding, sealing engagement with the upper section of the housing bore, the plunger having a lower plunger portion in sliding, sealing engagement with the lower section of the housing bore. A piston on the plunger moves in unison with the plunger and is in sliding, sealing engagement with the intermediate section of the housing bore. A lifting stroke port in the housing leads to the

intermediate section of the housing bore below the piston. A retracting stroke port in the housing leads to the intermediate section of the housing above the piston.

[0006] A hydraulic pump assembly for placement adjacent a wellhead of the well is in fluid communication with the lifting stroke port and the retracting stroke port. The hydraulic pump assembly has means for alternately supplying hydraulic fluid pressure to the lifting fluid port to cause the plunger to move upward, and for supplying hydraulic fluid pressure to the retracting fluid port to push the plunger downward. The housing has a well fluid intake and a standing valve for admitting well fluid into the housing during the lifting stroke of the plunger. The housing has a well fluid discharge. A travelling valve moves in unison with the plunger for discharging well fluid from the housing into the string of tubing during the lifting stroke of the plunger.

[0007] A retracting stroke fluid line leads from the retracting stroke port to the hydraulic pump assembly. A lifting stroke fluid line leads from the lifting stroke port to the hydraulic pump assembly. A directional control valve connected between the retracting stroke fluid line and the lifting stroke fluid line alternately shifts hydraulic fluid pressure between the lifting stroke fluid line and the retracting stroke fluid line.

[0008] In one embodiment, a lower adapter is secured to and forms a part of the housing. The lower adapter has an upward facing shoulder extending outward from an exterior of the housing. The lifting stroke port has an outer portion extending downward from the upward facing shoulder into the lower adapter. A lifting stroke line in fluid communication with the hydraulic pump assembly extends alongside the housing into the lifting stroke port, the lifting stroke line being parallel to an axis of the housing.

[0009] In one embodiment, an upper adapter is secured to and forms a part of the housing. The upper adapter is above the lower adapter and has an upward facing shoulder extending outward from the exterior of the housing. The retracting stroke port has an outer portion extending downward from the upward facing shoulder of the upper adapter into the upper adapter. A retracting stroke line in fluid communication with the hydraulic pump assembly extends alongside the housing into the retracting stroke port, the retracting stroke line being parallel to the axis of the housing.

[0010] In one embodiment, the lower adapter has a bore that is coaxial with the axis of the housing. The lower adapter has an outer diameter that is eccentric relative to the axis of the housing.

[0011] A plunger bore extends through the plunger. The travelling valve is mounted in the plunger bore. The plunger bore is in fluid communication with the standing valve for receiving well fluid from the well fluid intake.

Brief Description of the Drawings

[0012] Fig. 1 is a schematic sectional view of downhole well pump in accordance with this disclosure.

[0013] Fig. 2 is a schematic view of surface components for supplying hydraulic pressure to drive the well pump.

[0014] Fig. 3 is a sectional view of a more refined embodiment of the well pump of Figure 1.

[0015] Fig. 4 is another sectional view of the well pump of Fig. 3, taken from a different sectional plane.

[0016] Fig. 5 is an enlarged sectional view of a lower portion of the well pump of Fig. 3.

[0017] Fig. 6 is a perspective view of the well pump of Fig. 3.

[0018] While the disclosure will be described in connection with one embodiment, it will be understood that it is not intended to limit the disclosure to that embodiment. On the contrary, it is intended to cover all alternatives, modifications, and equivalents, as may be included within the scope of the claims.

Detailed Description

[0019] The method and system of the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings in which embodiments are shown. The method and system of the present disclosure may be in many different forms and should not be construed as limited to the illustrated embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will

fully convey its scope to those skilled in the art. Like numbers refer to like elements throughout. In an embodiment, usage of the term "about" includes +/- 5% of the cited magnitude. In an embodiment, usage of the term "substantially" includes +/- 5% of the cited magnitude.

[0020] It is to be further understood that the scope of the present disclosure is not limited to the exact details of construction, operation, exact materials, or embodiments shown and described, as modifications and equivalents will be apparent to one skilled in the art. In the drawings and specification, there have been disclosed illustrative embodiments and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation.

[0021] Fig. 1 schematically illustrates a well having a string of casing 11 cemented in the well and having perforations (not shown) or other openings for admitting well fluid. In this example, an outer string of tubing 13 is suspended in casing 11 from a wellhead assembly (not shown) at the surface. Outer tubing 13 is a conduit with an open lower end for admitting well fluid. An inner tubing 15 is suspended within outer tubing 13 and serves as a production tubing string for flowing well fluid to the wellhead assembly. Inner tubing 15 could be a continuous string of coiled tubing, or it could comprise tubular joints secured together. Optionally, one of the strings of outer and inner tubing 13, 15 could be omitted.

[0022] A hydraulically driven downhole pump 17 secures to the lower end of inner tubing 15. Downhole pump 17 has a barrel or housing 19 with an upper or retracting section 19a, an intermediate section 19b, and a lower or lifting section 19c, each having a common longitudinal axis 22. Intermediate section 19b has a larger inner diameter 20b than an inner diameter 20a of upper section 19a and inner diameter 20c of lower section 19c. Lower section 19c has an inner diameter equal to the inner diameter of upper section 19a, as shown, or it could be larger. Fig. 1 illustrates upper section 19a to have the same inner diameter as inner tubing 15, but that could differ. The inner diameters 20a, 20b and 20c of upper section 19a, intermediate section 19b and lower section 19c are polished bores. The terms "upper," "lower" and the like are used for convenience only, as downhole pump 17 could operate in other orientations than the one shown.

[0023] A plunger 21 strokes reciprocally within housing 19. Plunger 21 has a bore 23 extending through it on axis 22 of housing 19. Plunger 21 has an upper portion 25 that

reciprocally slides and seals within barrel upper section 19a. Plunger 21 has an intermediate piston 27 that slides and seals within housing intermediate section 19b. Plunger 21 has a lower portion 29 that slides and seals within housing lower section 19c. Each plunger portion 25, 27, 29 could have seals to dynamically seal to the inner diameter portions of housing 19, or plunger portions 25, 27, 29 could seal by a close sliding fit with the polished inner diameter portions 20a, 20b, 20c of housing 19. In this example, portions of plunger upper portion 25 and lower portion 29 have smaller outer diameters than the inner diameters 20a, 20c of upper and lower housing sections 19a, 19c. However, upper and lower portions 25, 29 of plunger 21 could have constant outer diameters extending from piston 27.

[0024] A lifting or upward stroke hydraulic fluid line 31 extends downward from the wellhead assembly through the annulus between outer and inner tubing 13, 15 to barrel intermediate sections 19b at a port 31a. Port 31a is below intermediate piston 27 when plunger 21 is in its lowest position. A retracting or downward stroke hydraulic fluid line 33 extends downward from the wellhead assembly through the annulus between outer and inner tubing 13, 15 to housing intermediate section 19b at a port 33a. Port 33a is above intermediate piston 27 when plunger 21 is in its uppermost position. Fig. 1 shows plunger 21 above its lowest position and in the process of moving upward in a lifting stroke.

[0025] Hydraulic fluid pressure is alternately supplied to lifting stroke line 31 and retracting stroke line 33. Hydraulic fluid pressure applied to lifting stroke line 31 while relieving the pressure in retracting stroke line 33 will apply fluid pressure to a lifting or lower chamber 34 in housing intermediate section 19b below piston 27. The difference in the smaller pressure area of lower plunger portion 29 and the larger pressure area of piston 27 creates an upward force on plunger 21, causing it to move upward. The difference in pressure areas is determined by the difference between inner diameter 20b of housing intermediate section 19b and inner diameter 20c housing lower section 19c.

[0026] Similarly, hydraulic fluid pressure applied to retracting stroke line 33 while relieving the pressure in lifting stroke line 31 will apply pressure to a retracting or upper chamber 36 above piston 27. The difference in the smaller pressure area of upper plunger portion 25 and the larger pressure area of piston 27 creates a downward force on plunger 21, causing it to move downward. The difference in pressure areas is caused by the difference between inner diameter 20b of housing intermediate section 19b and inner diameter 20a of housing upper section 19a.

[0027] A travelling valve 35 mounts to the upper end of plunger 21 and reciprocates in unison with plunger 21. Travelling valve 35 is a check valve of a type that is used with conventional reciprocating well pumps. These features include a ball 37 within a cage 40 and carried on a seat 39. When seated, ball 37 blocks well fluid previously pumped up inner tubing 15 from flowing downward into plunger bore 23. Ball 37 will be seated during an upstroke, lifting a column of well fluid within inner tubing 15. Well fluid flowing upward through plunger bore 23 during a downward stroke lifts ball 37 from seat 39, allowing the well fluid to flow into inner tubing 15.

[0028] Housing lower portion 19c includes a lower or tail pipe portion 41. Tail pipe 41 contains a standing valve 43 that does not move in unison with plunger 21. Standing valve 43 is also a check valve of conventional elements, including a ball 45 that lands on a seat 47 during the down stroke of plunger 21. When seated, ball 45 blocks a downward flow of well fluid within plunger bore 23. During the upward stroke, ball 45 lifts, admitting well fluid to plunger bore 23.

[0029] In this example, an optional safety valve 49 secures to the lower end of tail pipe 41. A hydraulic fluid line 51 extends downward from the wellhead assembly in the annulus between inner tubing 15 and outer tubing 13 to safety valve 49. Hydraulic pressure supplied to safety valve fluid line 51 maintains safety valve 51 open, allowing well fluid to flow up to standing valve 43. If the pressure is lost due to damage to the wellhead assembly, a spring within safety valve 49 causes it to close.

[0030] A packer 53 seals the annulus between barrel tail pipe 41 to the inner diameter of outer tubing 13. Packer 53 may be a variety of designs. For example, packer 53 could be run-in along with downhole pump 17, then set. One way to set packer 53 would be by hydraulic fluid pressure, and once set, the hydraulic fluid pressure could be relieved. For example, a packer setting line (not shown) could extend from one of the plunger stroking lines 31, 33 to packer 53 to cause packer 53 to set by supplying a setting pressure through one of the plunger stroking lines 31, 33 before operation of plunger 21.

[0031] Referring to Fig. 2, a hydraulic surface pump 55 adjacent to the wellhead assembly will alternately supply hydraulic fluid pressure to the lifting stroke and retracting stroke fluid lines 31, 33. Various hydraulic pumps and circuitry arrangements are feasible. In this embodiment, hydraulic pump 55 is a variable speed type having an output line 57 and

an intake line 58 having a filter 59. Intake line 58 leads to a tank 61. A pressure relief valve 63 limits the pressure in output line 57, and a check valve 65 prevents back flow in output line 57. An accumulator 67 connects to output line 57 upstream from check valve 65.

[0032] A directional control valve 69 shifts the pressure in output line 57 between lifting stroke fluid line 31 and retracting stroke fluid line 33. Directional control valve 69 has one position or mode 69a that directs hydraulic fluid pressure from surface pump 55 to retracting stroke line 33, which applies pressure to retracting chamber 36, pushing plunger 21 downward. In the first mode 69a, directional control valve 69 relieves fluid pressure in lifting stroke line 31 and lifting chamber 34 by directing the fluid into tank 61. Directional control valve 69 has a second mode 69b directing hydraulic fluid pressure from surface pump 55 to lifting stroke fluid line 31, which applies pressure to lifting chamber 34, pushing plunger 21 upward. In the second mode 69b, directional control valve 69 also relieves fluid pressure in retracting line 33 and retracting chamber 36 by directing the fluid into tank 61. A pressure sensor (not shown) in output line 57 leads to directional control valve 69 to cause it to shift from first mode 69a to second mode 69b.

[0033] Directional control valve 69 optionally may have a third mode 69c directing hydraulic fluid pressure from surface pump 55 to tank 61 and closing the upper ends of lines 31, 33, which causes downhole pump 17 to cease operating. The hydraulic system to drive downhole pump 17 may have conventional components to condition the hydraulic fluid during operation. Those components may include a filter 73 leading to a circulation pump 71 that draws hydraulic fluid from tank 61 and circulates the fluid through a heat exchanger 75 to cool the fluid.

[0034] During operation, hydraulic fluid pressure applied to lifting line 31 and lifting chamber 34 causes plunger 21 to move upward, pushing well fluid up inner tubing 15. At the upper end of the lifting stroke, directional control valve 69 shifts the hydraulic fluid pressure to retracting line 33 and retracting chamber 36, pushing plunger 21 downward and admitting well fluid into bore 23. Upper and lower plunger portions 25, 29 isolate the hydraulic fluid from contact with the well fluid. Control over the retracting stroke is not dependent on the weight of the well fluid in inner tubing 15. Any gas flowing from the well would not cause down hole downhole pump 17 to gas lock.

[0035] Figs. 3 – 6 illustrate a downhole pump 77 that is a more refined version of downhole pump 17 (Fig. 1). Downhole pump 77 operates in the same manner as downhole pump 17. Downhole pump 17 has a housing 79 with an upper portion 79a, an intermediate portion 79b and a lower portion 79c. Intermediate portion 79b has a larger inner diameter than upper and lower portions 79a, 79c. In this embodiment, portions 79a, 79b, and 79c are separate tubular members secured together. An upper adapter 81 joins housing upper portion 79a to housing intermediate portion 79b. A lower adapter 83 joins housing intermediate portion 79b to housing lower portion 79c. The joinders of adapters 81, 83 to housing 79 may be by threaded connections or other techniques.

[0036] As in the first embodiment, hydraulic fluid pressure strokes a plunger 85 between an upward lifting stroke and a downward retracting stroke. Plunger 85 has an upper portion 85a that slides sealingly in the bore of housing upper portion 79a. Plunger 85 has an intermediate portion 85b that slides sealingly in the bore of housing intermediate portion 79b. Plunger 85 has a lower portion 85c that slides sealingly in the bore of housing lower portion 79c.

[0037] A standing valve 87 in fluid communication with well fluid is mounted within the bore of housing lower portion 79c below plunger 85. A travelling valve 89 is mounted at the upper end of bore 91 of plunger 85.

[0038] Referring to Fig. 4, in this example, lower adapter 83 has a bore 93 with internal threads 95 secured to external threads on housing lower portion 79c, but that arrangement could be reversed. Lower adapter bore 93 is eccentric relative to the outer diameter 96 of lower adapter 83, which is also cylindrical. The axis of outer diameter 96 is offset relative to the axis of lower adapter bore 93. As a result, a portion of outer diameter 96 of lower adapter 83 protrudes outward from the exterior of housing lower portion 79c farther than the portion on the opposite side. Lower adapter 83 has external threads 97 that secure to internal threads in housing intermediate portion 79b, but that arrangement could be reversed.

[0039] Plunger lower portion 85c slides and strokes through lower adapter bore 93. An upper end 101 of lower adapter 83 is located internally within the bore of intermediate housing portion 79b. A bearing 103 fits within an annular recess in lower adapter bore 93 in sliding engagement with plunger lower portion 85c.

[0040] Lower adapter 83 has an external upward facing shoulder 107 that extends outward from the exterior of housing intermediate portion 79b. Because of the eccentricity of lower adapter 83, shoulder 107 has a greater width on one side than an opposite side. A lifting stroke port 109 extends through lower adapter 83 from the exterior to the bore of housing intermediate portion 79a. Lifting stroke port 109 has an outer portion 109a that extends downward from lower adapter shoulder 107 into lower adapter 83. Lifting stroke port 109 has a lateral portion 109b that extends radially inward from outer portion 109a. Lifting stroke port 109 has an inner portion 109c that extends upward from lateral portion 109b to lower adapter upper end 101.

[0041] A lifting stroke fluid line 111 extends alongside housing upper portion 79a and intermediate portion 79b into lifting stroke port outer portion 109a. The lower end of lifting stroke fluid line 111 may be joined to to lifting stroke port outer portion 109a of lower adapter 83 by various arrangements. For example, a shrink fit tube (not shown) could encircle a lower portion of lifting stroke fluid line 111 and sealingly join lifting stroke port outer portion 109a. Because of the eccentricity of adapter upper shoulder 107, no portion of lifting stroke fluid line 111 will be farther from axis 113 of housing 79 than outer diameter 96 of lower adapter 83. Also, the longitudinal axis of lifting stroke fluid line 111 will be parallel to housing axis 113. Lower adapter 83 provides a small overall diameter for downhole pump 77, including lifting stroke fluid line 111. The small overall outer diameter facilitates installing downhole pump 77 within a well conduit.

[0042] Referring to Fig. 6, upper adapter 81 may have the same configuration as lower adapter 83, except for a slot or recess 117 through which lifting stroke fluid line 111 passes. Retracting stroke fluid line 115 joins the retracting fluid port in upper adapter 81 and extends upward from upper adapter 81 alongside housing upper portion 79a in the same manner as lifting stroke fluid line 111. Retracting stroke fluid line 115 is circumferentially offset from lifting stroke fluid line 111.

[0043] The present disclosure described herein, therefore, is well adapted to carry out the objects and attain the ends and advantages mentioned, as well as others inherent therein. While one embodiment of the disclosure have been given for purposes of disclosure, numerous changes exist in the details of procedures for accomplishing the desired results. These and other similar modifications will readily suggest themselves to those skilled in the art, and are intended to be encompassed within the scope of the appended claims.

[0044] For example, if desired, a gas anchor could be mounted below safety valve 49 to separate gas by gravity and direct the separated gas through a port in packer 53 to the annulus between outer and inner tubing 13, 15. Another modification would be to pump the well fluid up the annulus between outer and inner tubing 13, 15 rather than within inner tubing 15. In that instance, inner tubing 15 could have apertures above traveling valve 35 to cause the upward flow through travelling valve 35 to flow into the annulus between outer tubing 13 and inner tubing 15. If only an outer tubing 13 is utilized and not an inner tubing 15, downhole pump 17 could be secured to the lower end of outer tubing 13 and hydraulic lines 31, 33 located on the outer side of outer tubing 13.

[0045] Also, one of the hydraulic fluid lines 31, 33 could be omitted, with hydraulic fluid pressure supplied to either lifting chamber 34 or retracting chamber 36 by pumping the hydraulic fluid down the annulus between outer and inner tubing 13, 15. Another alternative would be to make portions of plunger 21 retrievable from housing 19 for repair or replacement.

[0046] In addition, the well fluid pumping portion could be separated from the hydraulic driving portion. For example, a generally conventional reciprocating pump could be located above the hydraulic driving portion, which includes plunger 21 and housing 19. Housing 19 could extend upward to also house the standing valve and a separate pump plunger that is stroked by the plunger of the hydraulic driving portion. The travelling valve would be mounted to the pump plunger. The plunger of the hydraulic driving portion would not need a bore. Well fluid would bypass the hydraulic driving portion and flow into an intake in the portion of housing that serves as the well fluid pump.

Claims

1. An apparatus for pumping well fluid from a well, comprising:

a housing (19) for securing to a string of tubing (13);

a plunger (21) carried reciprocally in the housing between a lifting stroke and a retracting stroke;

a well fluid intake (45) in the housing;

a standing valve (43) in the housing for admitting well fluid from the well through the well fluid intake into the housing during the lifting stroke of the plunger;

a well fluid discharge (15) in the housing; and

a travelling valve (35) that moves in unison with the plunger for discharging well fluid from the housing out the well fluid discharge into the string of tubing during the lifting stroke of the plunger; characterized by:

the housing having a housing bore with an upper section (20a), a lower section (20c) and an intermediate section (20b) between the upper and lower sections, the intermediate section having a larger inner diameter than inner diameters of the upper and lower sections;

the plunger having an upper plunger portion (25) in sliding, sealing engagement with the upper section of the housing bore, the plunger having a lower plunger portion (29) in sliding, sealing engagement with the lower section of the housing bore;

a piston (27) on the plunger that moves in unison with the plunger and is in sliding, sealing engagement with the intermediate section of the housing bore;

a lifting stroke port (31a) in the housing leading to the intermediate section of the housing bore below the piston;

a retracting stroke port (33a) in the housing leading to the intermediate section of the housing above the piston; and

a hydraulic pump assembly (55) for placement adjacent a wellhead of the well and in fluid communication with the lifting stroke port and the retracting stroke port, the hydraulic pump assembly having means (69) for alternately supplying hydraulic fluid pressure to the lifting fluid port to cause the plunger to move upward, and for supplying hydraulic fluid pressure to the retracting fluid port to push the plunger downward.

2. The apparatus according to claim 1, further comprising:

a retracting stroke fluid line (33) leading from the retracting stroke port to the hydraulic pump assembly.

3. The apparatus according to claim 1, further comprising:

a lifting stroke fluid line (31) leading from the lifting stroke port to the hydraulic pump assembly.

4. The apparatus according to claim 1, further comprising:

a retracting stroke fluid line leading from the retracting stroke port to the hydraulic pump assembly;

a lifting stroke fluid line leading from the lifting stroke port to the hydraulic pump assembly; and wherein the means for alternately supplying hydraulic fluid pressure comprises:

a directional control valve (69) connected between the retracting stroke fluid line and the lifting stroke fluid line that alternately shifts hydraulic fluid pressure between the lifting stroke fluid line and the retracting stroke fluid line.

5. The apparatus according to claim 1, wherein the means for alternately supplying hydraulic fluid comprises:

a directional control valve that alternately shifts hydraulic fluid pressure between the lifting stroke port and the retracting stroke port.

6. The apparatus according to claim 1, further comprising:

a lower adapter (83) secured to and forming a part of the housing (79), the lower adapter having an upward facing shoulder (107) extending outward from an exterior of the housing;

the lifting stroke port (109) having an outer portion (109a) extending downward from the upward facing shoulder into the lower adapter; and

a lifting stroke line (111) in fluid communication with the hydraulic pump assembly and extending alongside the housing into the lifting stroke port, the lifting stroke line being parallel to an axis (113) of the housing.

7. The apparatus according to claim 6, further comprising:

an upper adapter (81) secured to and forming a part of the housing, the upper adapter being above the lower adapter and having an upward facing shoulder extending outward from the exterior of the housing;

the retracting stroke port having an outer portion extending downward from the upward facing shoulder of the upper adapter into the upper adapter;

a retracting stroke line (115) in fluid communication with the hydraulic pump assembly and extending alongside the housing into the retracting stroke port, the retracting stroke line being parallel to the axis of the housing.

8. The apparatus according to claim 6, wherein:

the lower adapter has a bore (93) that is coaxial with the axis of the housing; and

the lower adapter has an outer diameter (96) that is eccentric relative to the axis of the housing.

9. The apparatus according to claim 1, further comprising:

a plunger bore (23) extending through the plunger;

wherein the travelling valve is mounted in the plunger bore; and

the plunger bore is in fluid communication with the standing valve for receiving well fluid from the well fluid intake.

10. The apparatus according to claim 1, wherein the inner diameter of the lower section of the housing bore is at least equal to the inner diameter of the upper section of the housing bore.

11. The apparatus according to claim 1, wherein the standing valve is mounted in the lower section of the housing bore.

12. The apparatus according to claim 1, wherein:

the housing has a lower portion (79c) containing the lower section of the housing bore, an upper portion (79a) containing the upper section of the housing bore, and an intermediate portion (79b) containing the intermediate section of the housing bore; wherein the apparatus further comprises:

a lower adapter (83) connected between the lower portion and the intermediate portion of the housing, the lower adapter having an adapter bore (93) through which the lower portion of the plunger passes;

an outer portion (96) of the lower adapter extending laterally outward from the lower portion of the housing relative to a longitudinal axis (113) of the housing; and

wherein the lifting stroke port (109) extends through the outer portion of the lower adapter to the lower section of the housing bore.

13. The apparatus according to claim 12, wherein:

the outer portion of the lower adapter has an upward facing shoulder (107);

the lifting stroke port has an outer portion (109a) extending downward from the shoulder into the lower adapter;

the lifting stroke fluid line (111) has a lower end extending into the outer portion of the lifting stroke port; and

the lifting stroke fluid line extends alongside the intermediate and upper portions of the housing parallel to the axis.

14. A method of pumping well fluid from a well with a downhole hydraulic drive (17) comprising:

a housing (19) suspended on production tubing (13) in the well;

a plunger (21) carried reciprocally in the housing between a lifting stroke and a retracting stroke;

a standing valve (43) in the housing in fluid communication with well fluid in the well; and

a travelling valve (35) that moves in unison with the plunger and is in fluid communication with the production tubing; characterized by:

the housing having a housing bore with an upper section (20a), a lower section (20c) and an intermediate section (20b) between the upper and lower sections, the intermediate section having a larger inner diameter than inner diameters of the upper and lower sections;

the plunger having an upper plunger portion (25) in sliding, sealing engagement with the upper section of the housing bore, the plunger having a lower plunger portion (29) in sliding, sealing engagement with the lower section of the housing bore; and

a piston (27) on the plunger that moves in unison with the plunger and is in sliding, sealing engagement with the intermediate section of the housing bore; the method comprising:

supplying hydraulic fluid pressure to the intermediate section of the housing bore below the piston to cause the plunger to move upward in the lifting stroke;

opening the standing valve and closing the travelling valve to lift a column of fluid in the production tubing during the lifting stroke; then

supplying hydraulic fluid pressure to the intermediate section of the housing bore above the piston to push the plunger downward in the retracting stroke; and

closing the standing valve and opening the travelling valve during the retracting stroke.

15. The method according to claim 14, wherein:

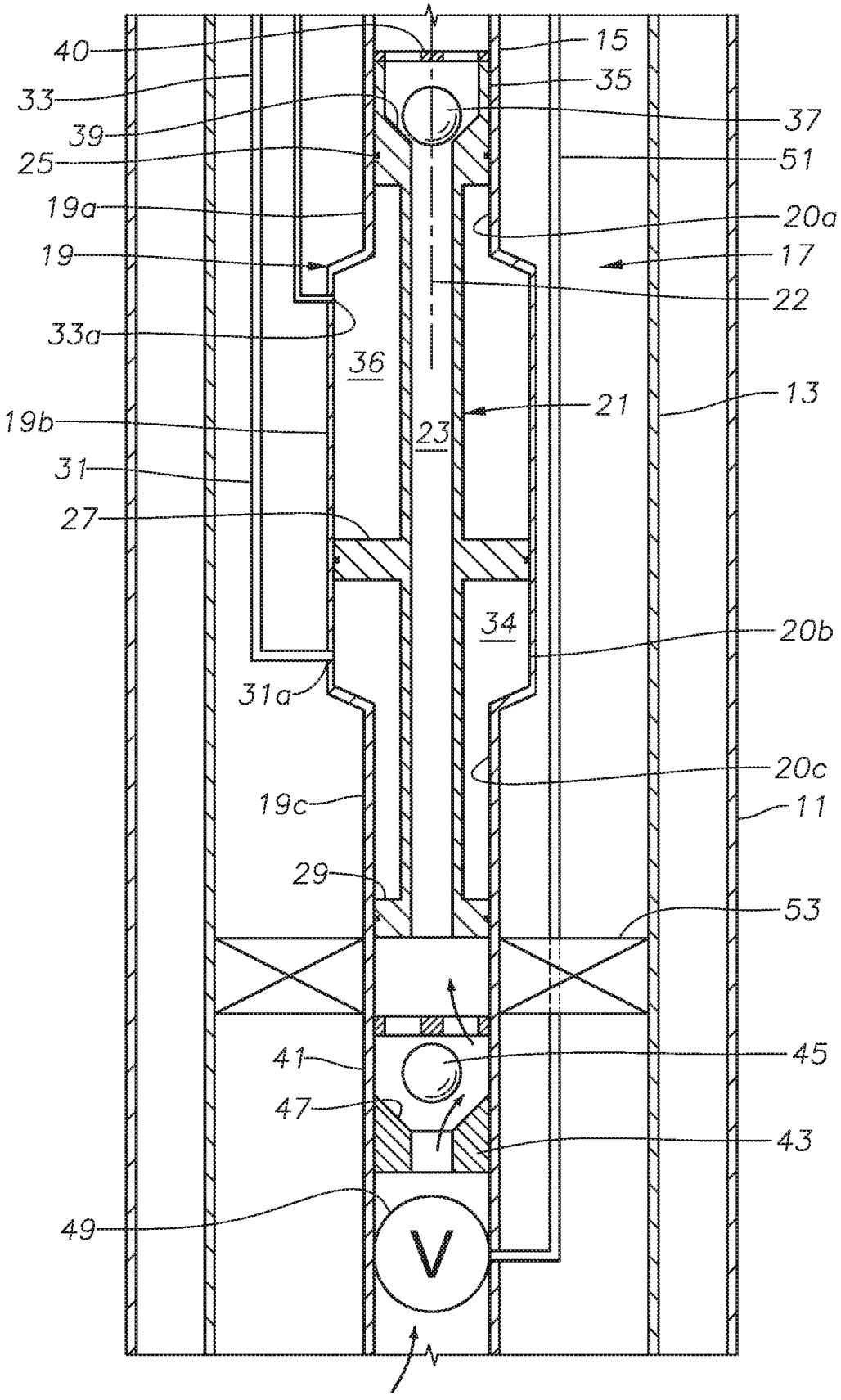
the plunger has a plunger bore (23) extending therethrough;

the travelling valve is mounted in the plunger bore; and

the standing valve is located below the lower plunger portion; and the method further comprises:

flowing well fluid through the standing valve into the plunger bore during the lifting stroke; and

blocking well fluid from flowing downward out of the plunger bore and through the standing valve during the retracting stroke.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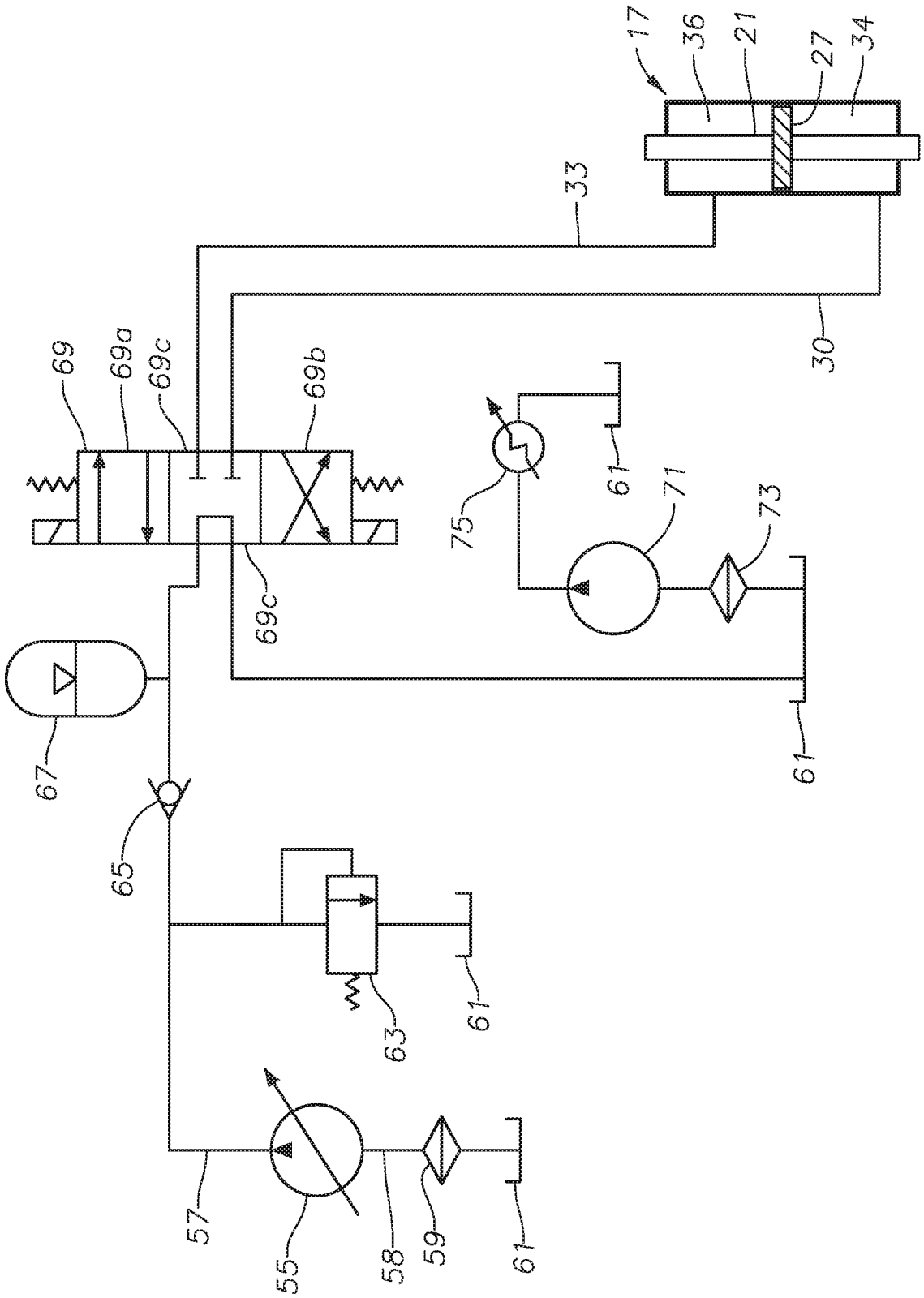
39
25
19a
19
33a
19b
31
27
31a
19c
29
41
47
49
15
35
37
51
20a
17
22
36
21
13
23
34
20b
20c
11
53
45
43
V

FIG. 1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34
33
30
69
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69c
69b
69c
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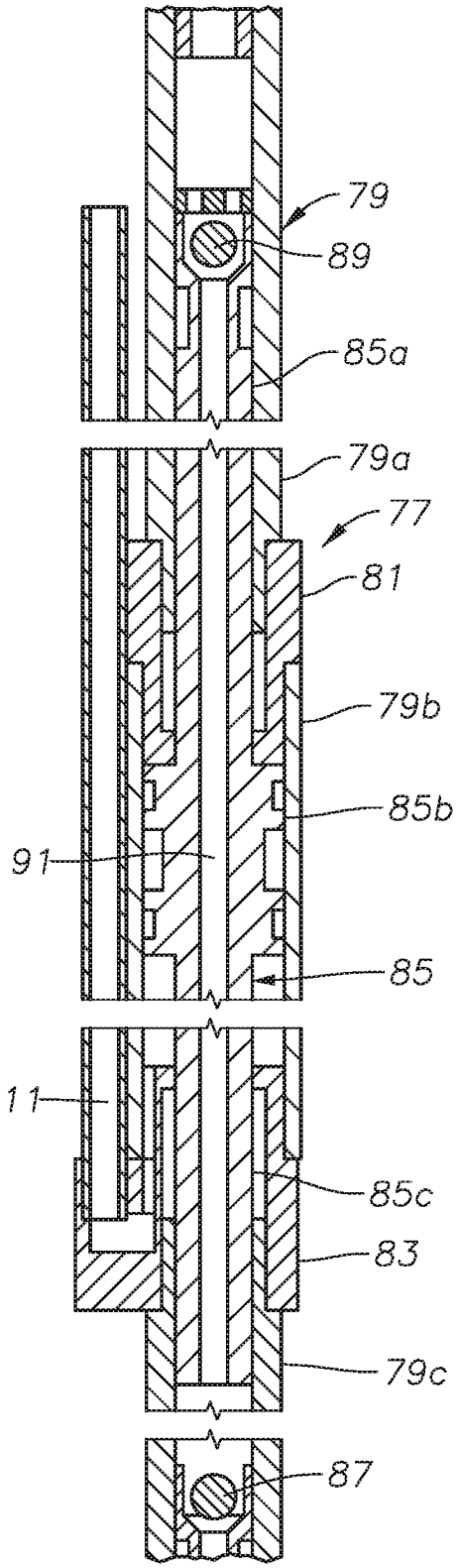
63
61
57
55
58
59
61

FIG. 2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79a
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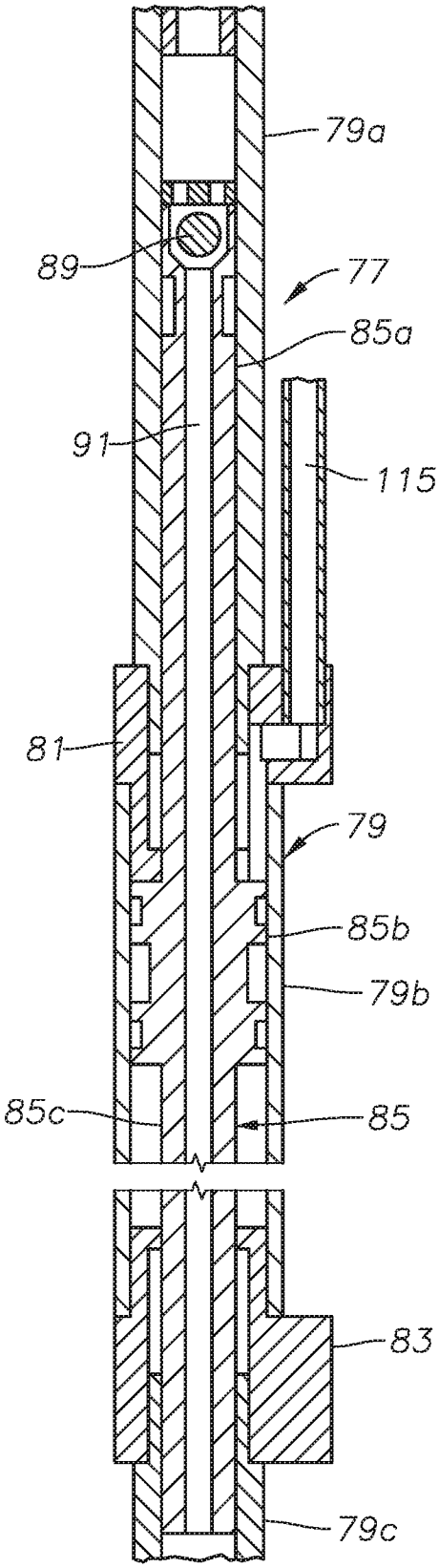
81
79b
85b
91
85
11
85c
83
79c
87

FIG. 3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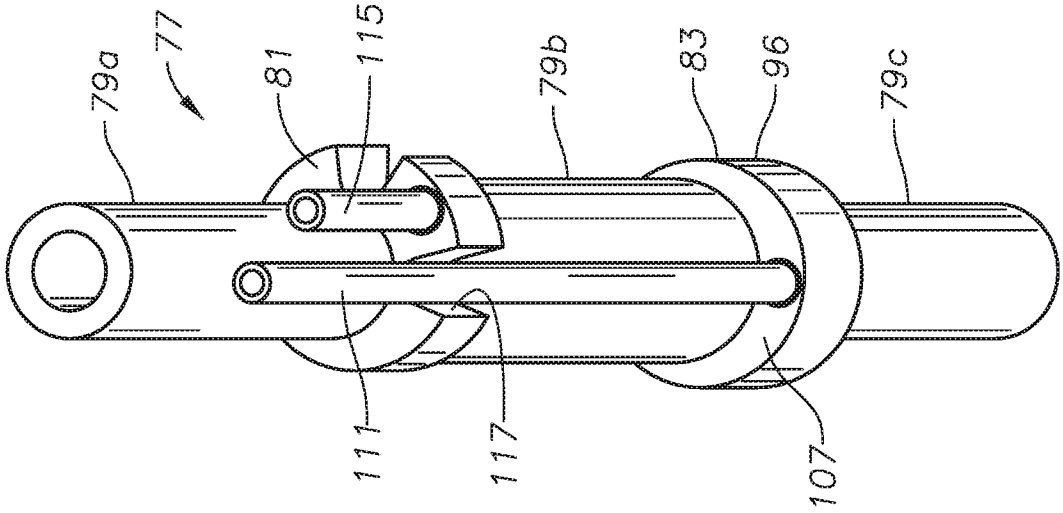
77
85a
91
115
81
79
85b
79b
85c
85
83
79c

FIG. 4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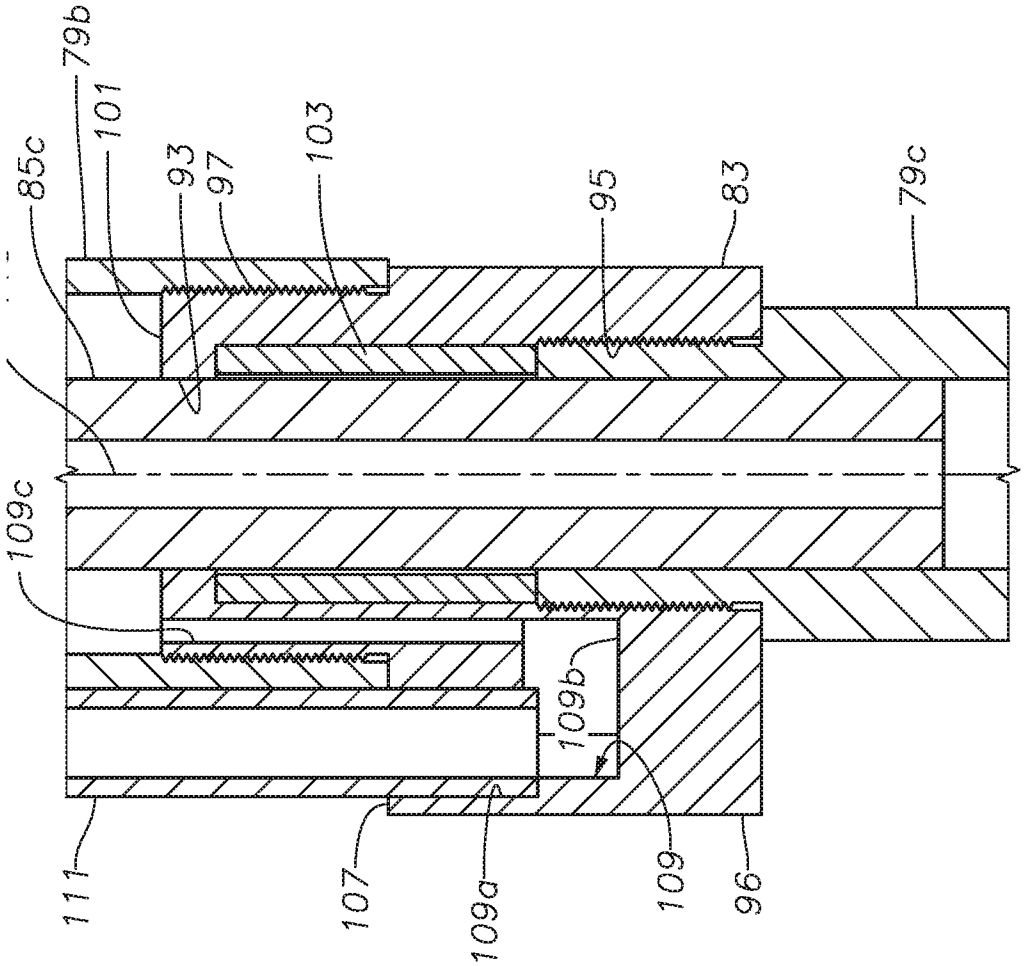
81
115
79b
83
96
79c
111
117
107

FIG. 6


79b
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85c
93
97
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95
83
79c
109c
109b
111
107
109a
109
96

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2020/016409

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/12(2006.01)i, F04B 47/08(2006.01)i, F04B 53/14(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B 43/12; E21B 34/08; E21B 43/00; F04B 47/02; F04B 47/04; F04B 47/08; F04B 9/103; F04B 53/14

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: pump, piston, valve, hydraulic, reciprocating

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 7134499 B2 (WILSON et al.) 14 November 2006 column 2, line 52 - column 3, line 53, column 4, lines 30-51, claims 1, 6, 16, and figures 1A-4	1-15
Y	US 9863415 B2 (1238585 ALBERTA LTD.) 09 January 2018 column 3, lines 1-20 and figure 1	1-15
Y	US 4405291 A (CANALIZO, CARLOS R.) 20 September 1983 column 8, lines 14-40 and figure 6	6-8,12-13
A	US 5996688 A (SCHULTZ et al.) 07 December 1999 claim 1 and figure 1	1-15
A	WO 2013-082386 A1 (SCHLUMBERGER CANADA LIMITED et al.) 06 June 2013 claim 1 and figures 1-5	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"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 May 2020 (27.05.2020)	**27 May 2020 (27.05.2020)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2020/016409

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