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(71) Applicant *(for CA only)*: **SCHLUMBERGER CANADA LIMITED** [CA/CA]; 125 - 9 Avenue SE, Calgary, Alberta T2G 0P6 (CA).

(71) Applicant *(for FR only)*: **SERVICES PETROLIERS SCHLUMBERGER** [FR/FR]; 42 rue Saint Dominique, F-75007 Paris (FR).

(71) Applicant *(for GB, JP, NL only)*: **SCHLUMBERGER HOLDINGS LIMITED**; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola, Virgin Islands, British, 1110 (VG).

(71) Applicant *(for all designated States except AE, AO, BH, CA, CN, FR, GB, GH, IN, JP, LY, MA, MZ, NA, NG, NL, PH, SD, SY, US, VN)*: **SCHLUMBERGER TECHNOLOGY B.V.** [NL/NL]; Parkstraat 83-89m, NL-2514 JG The Hague (NL).

(71) Applicant *(for AE, AO, BF, BH, BJ, CF, CG, CI, CM, CN, GA, GH, GN, GQ, GW, IN, KM, LY, MA, ML, MR, MZ, NA, NE, NG, PH, SD, SN, SY, TD, TG, VN only)*: **PRAD RESEARCH AND DEVELOPMENT LIMITED**; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola, Virgin Island, British, 1110 (VG).

(71) Applicant *(for US only)*: **SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Sugar Land, Texas 77478 (US).

(72) Inventors: **RODRIGUEZ, Juan Carlos**; Humboldt 630, Quito (EC). **ESQUIVEL, Wilson**; Moises Luna Andrade Oe2-199 y Mariano, Paredes, Quito (EC). **CADENA PARGA, Edgar Mauricio**; Av. 12 de Octubre N24-593 y Francisco Salazar, Quito (EC). **CARMONA, Fabiola**; Av. 12 de Octubre N24-593 y Francisco Salazar, Quito (EC). **RIVAS ROMERO, Olegario**; 8004 Stoneyway Drive, Houston, Texas 77040 (US).

[Continued on next page]

(54) **Title**: BOTTOM HOLE INJECTION WITH PUMP

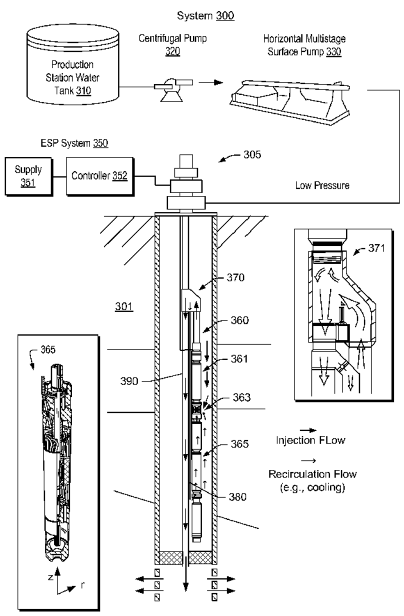

Fig. 3

(57) Abstract: A method can include flowing water into an upper portion of a well; receiving the water at an intake of an electric submersible pump disposed in the well; pumping the water toward the upper portion of the well via the electric submersible pump; receiving the pumped water at a header; and directing a portion of the water from the header to a recirculation conduit that includes an opening proximate to a motor of the electric submersible pump and directing another portion of the water from the header to tubing that includes an opening sealed from the intake of the pump.

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(74) Agents: **STONEBROOK, Michael** et al.; 10001 Richmond Avenue, IP Administration Center of Excellence, Room 4720, Houston, Texas 77042 (US).

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BOTTOM HOLE INJECTION WITH PUMP

RELATED APPLICATION

[0001] This application claims priority to and the benefit of a U.S. Provisional Patent Application having Serial No. 62/047,833, filed 9 September 2014, which is incorporated by reference herein.

BACKGROUND

[0002] As an example, a well may produce water. In such an example, the water may be a nuisance. For example, where the water is in a multiphase mixture that includes one or more hydrocarbons. Handling of water may include disposal.

SUMMARY

[0003] A method can include flowing water into an upper portion of a well; receiving the water at an intake of an electric submersible pump disposed in the well; pumping the water toward the upper portion of the well via the electric submersible pump; receiving the pumped water at a header; and directing a portion of the water from the header to a recirculation conduit that includes an opening proximate to a motor of the electric submersible pump and directing another portion of the water from the header to tubing that includes an opening sealed from the intake of the pump. A system can include a header that includes side pocket mandrel, an electric submersible pump mount, a tubing mount and a recirculation conduit mount. A system can include a header that includes a mandrel, a valve, an electric submersible pump mount, a tubing mount and a recirculation conduit mount; tubing operatively coupled to the tubing mount; a recirculation conduit operatively coupled to the recirculation conduit mount where the valve controls flow of fluid to the recirculation conduit; and an electric submersible pump operatively coupled to the electric submersible pump mount where the electric submersible pump includes, in an axial order with respect to an axis of the electric submersible pump, a pump, a pump inlet and an electric motor and where the recirculation conduit extends axially past the pump inlet to an opening that is located axially even with or axially past the electric motor.

[0004] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to

identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Features and advantages of the described implementations can be more readily understood by reference to the following description taken in conjunction with the accompanying drawings.

[0006] Fig. 1 illustrates an example of a system;

[0007] Fig. 2 illustrates an example of a system;

[0008] Fig. 3 illustrates an example of a system;

[0009] Fig. 4 illustrates an example of a system;

[0010] Fig. 5 illustrates an example of a system;

[0011] Fig. 6 illustrates an example of subsystem;

[0012] Fig. 7 illustrates an example of a system; and

[0013] Fig. 8 illustrates an example of a method.

DETAILED DESCRIPTION

[0014] The following description includes the best mode presently contemplated for practicing the described implementations. This description is not to be taken in a limiting sense, but rather is made merely for the purpose of describing the general principles of the implementations. The scope of the described implementations should be ascertained with reference to the issued claims.

[0015] Production water can be a sub-product obtained from oil and gas reservoirs. As to utilization of production water, a process may use at least a portion of produced water in a pressure reservoir enhanced recovery process, in a flooding process (e.g., as a flooding agent), in a hydraulic fracturing process, etc. Production water may be a nuisance, for example, where large quantities may be considered a waste sub-product, which has associated handling issues.

[0016] As an example, the cost of lifting a barrel of water from the subsurface of an oil bearing formation may be higher than the cost of lifting a barrel of commercial-grade crude oil, for example, due at least in part to the quantity of chemicals that may be introduced for purposes of stability, etc. (e.g., anti-scale, anti-corrosion, anti-paraffin, biocides, etc.). Once an oil-water mixture has reached the surface, the oil fraction may be separated via one or more separators and transported for further processing as to one or more products (e.g., with commercial value).

[0017] As mentioned, water may be a nuisance that can consume resources for disposal. As an example, water from one well of a formation may be, for example, returned to the formation or another formation (e.g., consider a disposal reservoir, etc. capable of receiving fluid under gravity, by pressure injection, etc.). As an example, a regulatory structure may exist that calls for adequate disposal facilities for a first water production barrel.

[0018] As to water injection, bottlenecks can exist. For example, consider: corrosion and scales in one or more high pressure flow lines constraining the operation pressures; risk associated with transfer of water between high pressure pump stations to an injection well(s) in surface pipelines; restriction due to land / legal surface owner issues; availability, cost and time of high pressure pipelines; Insufficient quantity of disposal wells; and Insufficient injection pump capacity at production stations. Such concerns may impact decisions as to high water cut production wells. For example, water disposal constraints may imply that production wells with a high water cut may be considered for being shut-in, restricted in their production capacity, etc.

[0019] As an example, a method can include using an existing production well for water injection. For example, an existing production well that may be producing below a particular quantity of oil (e.g., below an expected quantity, etc.) may, for example, be converted to an injection well or, for example, a new water injection well with limited capacity in high pressure transfer from station to one or more locations, using a particular pump, which may be an electric submersible pump (ESP) that may be fit within a completion in a well to pump water.

[0020] As an example, a system can include availability of a water flow line from a source to an injection well, power at a well location (e.g., electrical via utility, turbine generator, etc.), and readiness of a work-over (WO) rig for the well completion.

[0021] Fig. 1 shows an example of a system 100 that includes a geologic environment 120 with a well 130 where the well 130 includes a well head 131, a pipe 132, a casing 135, conduit 136, a packer 138 and perforations 139. Also shown in Fig. 1 are one or more compressors 150 for compressing gas, a well manifold 160, one or more separators 170, a tanks and piping sub-system 180 and a pump 190.

As shown, the pump 190 may be implemented to pump water into the geologic environment 120 via the well 130.

[0022] As illustrated in Fig. 1, water can be injected in a disposal well in a field, in which a production station includes specific facilities for water treatment like water tanks, booster pumps, horizontal multistage injection pumps, high pressure injection pipelines and ancillary equipment (air, electric, chemical, etc.). Fig. 1 shows equipment that may be part of such a water disposal system. Feasibility of such a system may depend on factors such as well head high injection pressure, which can be a condition that can vary from reservoir to reservoir, as well as the average well injection rate.

[0023] Fig. 2 shows an example of a system 200 that includes a geologic environment 201 that includes a well 205. As shown, water may be injected via the well 205 into the geologic environment 201 using various pumps. For example, a production station water tank 210 can feed a centrifugal pump 220 that delivers water from the tank 210 to a horizontal multistage surface pump 230, which may pump water via one or more pipelines to an in situ water tank 240. The water tank 240 may supply water to a centrifugal pump 250 that can feed a horizontal multistage surface pump 260. As shown, the horizontal multistage surface pump 260 may inject water into the geologic environment 201 via the well 205.

[0024] As an example, an oil producer may use of horizontal centrifugal multistage surface pumps (HPS) installed at a well pad that can receive water from a production station trough low pressure surface pipelines. In such an example, pump discharge can be connected to a wellhead of an injection well to inject the water into the injection well. Such an approach involves a system that may span a substantial geographical region (e.g., footprint) and associated cost and time associated to develop such surface facilities may be substantial.

[0025] Fig. 3 shows an example of a system 300 that includes a geologic environment 301 that includes a well 305. As shown, water may be injected via the well 305 into the geologic environment 301 using an electric submersible pump system 350 that includes a power supply 351 (e.g., from a utility, from a generator, etc.), a controller 352 and an electric submersible pump (ESP) 360. As an example, the well 305 may be cased and/or cemented where casing may be of a diameter from about 15 cm to about 30 cm. In such an example, the ESP 360 may be of a maximum diameter of about 5 cm to about 20 cm (e.g., or more).

[0026] As an example, an ESP may include an electric motor with a rotating shaft and/or with a reciprocating shaft (e.g., a linear motion electric motor). As an example, an ESP suitable for implementation in the system 300 may include a pump that includes one or more rotatable elements (e.g., one or more rotatable impellers) or that includes one or more translatable elements (e.g., one or more pistons). As an example, where an ESP includes an electric motor that is positioned in a manner whereby pumped fluid (e.g., or fluid to be pumped) may not flow adjacent to the electric motor and extract heat energy therefrom, an implementation may employ a recirculation cooling sub-system to help extract heat energy from the electric motor (e.g., at least in part via one or more recirculation conduits, etc.).

[0027] In the example of Fig. 3, the ESP 360 includes a pump 361, an inlet 363 for the pump 361 and an electric motor 365. As an example, a shaft of the electric motor 365 may define an axis (e.g., a z-axis) of the ESP 360. Such a shaft may be operatively coupled to a shaft of the pump 361, optionally coupled via an intermediate shaft that may pass through a protector that is disposed at least in part axially between the electric motor 365 and the pump 361. In the example of Fig. 3, the inlet 363 for the pump 361 is disposed axially above the electric motor 365.

[0028] In the example of Fig. 3, the system 300 can include a header 370 and a recirculation conduit 380 where the header 370 receives water pumped by the ESP 360 and can direct a portion of the water to the recirculation conduit 380 and a portion of the water to tubing 390. As shown, the recirculation conduit 380 can include an opening disposed at or below a level of the electric motor 365 of the ESP 360, for example, to flow water that can contact a motor housing and extract heat energy from the motor housing, for example, to help cool the electric motor 365.

[0029] As an example, a system can include a regulator that may regulate flow of water to a recirculation conduit or recirculation conduits that can direct water proximate to an electric motor of a pump, for example, to help remove heat energy from the electric motor, to control temperature of the electric motor, etc.

[0030] In the example of Fig. 3, the header 370 may include a plurality of components, bores, etc. As an example, the header 370 can include a Y-tool. For example, consider a Y-tool that includes a main bore and an offset bore. As an example, a Y-tool may include yet another bore, for example, to direct flow of fluid to a recirculation conduit (e.g., capillary tubing, etc.). As an example, a Y-tool may include one or more valves. For example, a Y-tool may include a flapper valve, flapper valves and/or one or more other types of valves. As an example, a valve of a Y-tool may be operated manually, for example, via a tool, and/or automatically, for example, via a pressure triggering mechanism, etc. As an example, a flapper valve may be actuated via pressure (e.g., a pressure differential).

[0031] In Fig. 3, an example header 371 is shown where a Y-tool can be plugged at an upper end such that fluid flows in a U-shaped path. As an example, a component operatively coupled to such a Y-tool (e.g., part of the header 371) may include a branch (e.g., a Y) that can direct a portion of flowing fluid to a recirculation conduit or recirculation conduits. For example, consider two branches where one branch is disposed to one side of a pump and another branch is disposed to another side of the pump such that recirculation conduits can deliver cooling fluid to at least two regions adjacent an electric motor of a pump. As an example, one or more of a forked branch, staggered branches, etc., may be employed.

[0032] As an example, a component or components above a Y-tool may be part of a header. For example, consider a branched tubing positioned above the Y-tool of the example header 371 where a branch is in fluid communication with a recirculation conduit. In such an example, fluid may flow upward above the Y-tool and then downward via a recirculation conduit or recirculation conduits. As an example, a side pocket mandrel may be utilized as a branched component, optionally including a valve that may regulate flow to a recirculation conduit. As an example, an upper end of a side pocket mandrel may be plugged, optionally via a controllable (e.g., adjustable plug).

[0033] As shown in the example of Fig. 3, a production station water tank 310 can feed a centrifugal pump 320 that delivers water from the tank 310 to a horizontal multistage surface pump 330, which may pump water via one or more pipelines to the ESP 360. In such an example, the one or more pipelines may deliver water to the well site of the well 305 at a first pressure where the ESP 360 elevates the pressure of the water to a second higher pressure. As mentioned, to implement such a scheme, a rig may be available at the well site of the well 305, for example, to facilitate positioning of the ESP 360 in the well 305.

[0034] As an example, a method can include discharging low pressure injection water to an injection well where the injection water may be pumped, for example, from a water tank to the wellhead at low pressure through a surface pipeline. Within the well, a completion may include an ESP that can receive the water and discharge it at a higher pressure. In such an example, a method can include pumping injecting water into a geologic environment via a pump disposed in an injection well.

[0035] Fig. 4 shows an example of an ESP system 400 that includes an ESP 410 as an example of equipment that may be placed in a geologic environment. As an example, commercially available ESPs (such as the REDA™ ESPs marketed by Schlumberger Limited, Houston, Texas) may be employed in a well. As an example, the ESP system 400 may be configured for injecting water into a geologic environment via a well. For example, the ESP 410 may be controlled in a manner to inject water via a well (e.g., as implemented in a system such as, for example, the system 300, etc.). As an example, an ESP system implemented for water injection may include various features of the ESP system 400. As an example, an ESP system implemented for water injection may features of the ESP system 400 and/or other features. As an example, an ESP may be configured in a completion suited for injection of water.

[0036] In the example of Fig. 4, the ESP system 400 may be coupled to a network 401 and various components may be disposed in a well 403 in a geologic environment (e.g., with surface equipment, etc.). As shown, the ESP system can include a power supply 405, the ESP 410, a controller 430, a motor controller 450 and a VSD unit 470. The power supply 405 may receive power from a power grid, an onsite generator (e.g., natural gas driven turbine), or other source. The power supply 405 may supply a voltage, for example, of about 4.16 kV.

[0037] As an example, the controller 430 may include one or more processors, memory and one or more interfaces (e.g., information interfaces, power interfaces, power and information interfaces, etc.). As an example, a system may include one or more computers. As an example, a system may include one or more computer-readable storage media that include processor-executable instructions that can instruct a device, a system, etc. to perform one or more actions. As an example, a computer-readable storage medium may be non-transitory and not a carrier wave.

[0038] As shown, the well 403 includes a wellhead that can include a choke (e.g., a choke valve). For example, the well 403 can include a choke valve to control various operations such as to reduce pressure of a fluid from high pressure in a closed wellbore to atmospheric pressure. Adjustable choke valves can include valves constructed to resist wear due to high-velocity, solids-laden fluid flowing by restricting or sealing elements. A wellhead may include one or more sensors such as a temperature sensor, a pressure sensor, a solids sensor, etc. A wellhead may include one or more couplings, for example, to couple one or more conduits to the wellhead.

[0039] As to the ESP 410, it is shown as including cables 411 (e.g., or a cable), a pump 412, gas handling features 413, a pump intake 414, a motor 415, one or more sensors 416 (e.g., temperature, pressure, strain, current leakage, vibration, etc.) and optionally a protector 417.

[0040] As an example, an ESP motor can include a three-phase squirrel cage with two-pole induction. As an example, an ESP motor may include steel stator laminations that can help focus magnetic forces on rotors, for example, to help reduce energy loss. As an example, stator windings can include copper and insulation.

[0041] In the example of Fig. 4, the well 403 may include one or more well sensors 420. In the example of Fig. 4, the controller 430 can include one or more interfaces, for example, for receipt, transmission or receipt and transmission of information with the motor controller 450, a VSD unit 470, the power supply 405 (e.g., a gas fueled turbine generator, a power company, etc.), the network 401, equipment in the well 403, equipment in another well, etc.

[0042] As shown in Fig. 4, the controller 430 may include or provide access to one or more modules or frameworks. Further, the controller 430 may include features of an ESP motor controller and optionally supplant the ESP motor controller 450. For example, the controller 430 may include the UNICONN™ motor controller 482 marketed by Schlumberger Limited (Houston, Texas). In the example of Fig. 4, the controller 430 may access one or more of the PIPESIM™ framework 484, the ECLIPSE™ framework 486 marketed by Schlumberger Limited (Houston, Texas) and the PETREL™ framework 488 marketed by Schlumberger Limited (Houston, Texas) (e.g., and optionally the OCEAN™ framework marketed by Schlumberger Limited (Houston, Texas)).

[0043] As an example, the one or more sensors 416 of the ESP 410 may be part of a digital downhole monitoring system. For example, consider the commercially available PHOENIX™ Multisensor xt150 system marketed by Schlumberger Limited (Houston, Texas). A monitoring system may include a base unit that operatively couples to an ESP motor (see, e.g., the motor 415), for example, directly, via a motor-base crossover, etc. As an example, such a base unit (e.g., base gauge) may measure intake pressure, intake temperature, motor oil temperature, motor winding temperature, vibration, currently leakage, etc.

[0044] As an example, for FSD controllers, the UNICONN™ motor controller can monitor ESP system three-phase currents, three-phase surface voltage, supply voltage and frequency, ESP spinning frequency and leg ground, power factor and motor load.

[0045] As an example, for VSD units, the UNICONN™ motor controller can monitor VSD output current, ESP running current, VSD output voltage, supply voltage, VSD input and VSD output power, VSD output frequency, drive loading, motor load, three-phase ESP running current, three-phase VSD input or output voltage, ESP spinning frequency, and leg-ground.

[0046] In the example of Fig. 4, the VSD unit 470 may be a low voltage drive (LVD) unit, a medium voltage drive (MVD) unit or other type of unit (e.g., a high voltage drive, which may provide a voltage in excess of about 4.16 kV). As an example, the VSD unit 470 may receive power with a voltage of about 4.16 kV and control a motor as a load with a voltage from about 0 V to about 4.16 kV. The VSD unit 470 may include commercially available control circuitry such as the SPEEDSTAR™ MVD control circuitry marketed by Schlumberger Limited (Houston, Texas).

[0047] As an example, the controller 430 of the ESP system 400 of Fig. 4 may include one or more features for control of recirculation of fluid. For example, where one or more electric motor cooling sub-system components includes a sensor, sensors, a valve, valves, etc., the controller 430 may be operatively coupled to receive and/or to transmit signals of such one or more components. For example, where a temperature sensor indicates that temperature of an electric motor may be elevated, rising at a particular rate, etc., the controller 430 may receive temperature information and respond via transmitting one or more signals to control one or more components of an electric motor cooling sub-system (e.g., and/or to one or more other components of an ESP, etc.) to effectuate control of the temperature of the electric motor. For example, consider increasing flow to a recirculation conduit, decreasing speed of the electric motor, etc.

[0048] Fig. 5 shows an example of a system 500 that includes a completion that can include an electric motor cooling sub-system for cooling an electric motor

514 of a pump assembly where the electric motor 514 is operatively coupled to a pump 510 of the pump assembly. Such a system may be used for water injection in a completion for delivery of water to a subsurface environment, for example, to move produced water to a desired formation for disposal and/or one or more other purposes. For example, a power cable 522 may operatively couple the electric motor 514 to one or more power control units 501 and 502 such that the electric motor 514 can drive the pump 510, which, in turn, can pump fluid (e.g., water) that can be directed, at least in part, via bypass tubing 511 to a region or regions of a formation (e.g., or formations).

[0049] As an example, in the system 500, water can flow from a production station through one or more pipelines and enter, via a well head assembly 503, an annular space 504 between casing 505 and tubing 506.

[0050] In the example of Fig. 5, a trajectory depth is shown with respect to a z-axis, noting that a well may be deviated (e.g., deviated from vertical and optionally substantially horizontal). As an example, the electric motor 514 may be disposed at a depth that is greater than a depth of the pump 510 (e.g., deeper into a well), particularly deeper than an inlet 512 for the pump 510. In such an example, a flow path or flow paths for water entering the inlet 512 may not flow past a surface or surfaces of the electric motor 514. For example, consider one or more flow paths in the annular space 504 above the inlet 512 that may be considered one or more main flow paths for water to the inlet 512. As the electric motor 514 generates heat energy during operation (e.g., as may be characterized in part by efficiency being less than 100 percent), the temperature of the electric motor 514 may rise during its operation. To cool the electric motor 514, the electric motor cooling sub-system may be implemented in a manner that can direct water (e.g., an aqueous fluid moved by the pump 510) to a surface or surfaces of at least a portion of the electric motor 514. At least a portion of such water may then be drawn into the inlet 512 and pumped via the pump 510, for example, to a downhole location (e.g., as injection fluid).

[0051] In the example of Fig. 5, erosion or damage prevention as to the power cable 522 and the tubing 506 may optionally be achieved, at least in part, by a reduction of the injection water velocity (e.g., because of the bigger cross-sectional area of the annulus compared to the tubing). In the example of Fig. 5, a packer 520 may provide a seal between upper and lower tubing sections (e.g., act as a hydraulic seal to define at least in part an upper chamber or space and a lower chamber or space, etc.).

[0052] In the example of Fig. 5, the system 500 may ensure enough water flow passing the electric motor 514, for example, to provide cooling, for example, using an arrangement that includes a wireline compatible check valve or blanking plug 524, a side pocket mandrel 507 with a flow regulator valve 525 (e.g., operatively coupled to and/or disposed within the side pocket mandrel 507) and capillary tubing 523 (see also, e.g., Fig. 6) that can receive fluid that may flow through the side pocket mandrel 507. In such an example, injection water can flow from the wellhead assembly 503 to the inlet 512 (e.g., a pump intake) through the well injection annular space 504, and can be boosted to a desired injection pressure. From a pump discharge conduit 509, pumped water can flow through a Y-tool 508 (e.g., downwardly with respect to the trajectory depth) where at least a portion of the pumped water can flow to injection tubing 517, for example, to be directed to an injection region 521 for injection to a formation. As an example, a portion of pumped water may flow through the Y-tool 508 (e.g., upwardly with respect to the trajectory depth) to the side pocket mandrel 507 where it may be directed to the capillary tubing 523.

[0053] In the example of Fig. 5, along the trajectory depth, a recirculation turn depth and an outlet depth are indicated, which can define a recirculation path (e.g., a recirculation path length). As an example, the side pocket mandrel 507 and flow regulator valve 525 may define the recirculation turn depth and an outlet or outlets of the capillary tubing may define an outlet depth or depths for recirculated fluid. As shown in the example of Fig. 5, the outlet depth of the capillary tubing 523 is greater than the depth of the electric motor 514. In such an example, fluid may exit one or more outlets of the capillary tubing 523 and then pass along one or more surfaces of the electric motor 514 (e.g., as the packer 520 seals the space below the capillary tubing 523).

[0054] As an example, installation and servicing of the pump system of the system 500 may be accomplished without the intervention of a work-over rig; for example, if servicing is desired, the pump system can be pulled with a pulling rig.

[0055] In the example of Fig. 5, the pump system is illustrated as an electric submersible pump (ESP) that includes the electric motor 514 that is installed in a well (e.g., in a bore defined by the casing 505) to drive the pump 510 to pump at least a portion of injection water to the reservoir receiving formation (e.g., at an injection region or regions) at a desired injection pressure.

[0056] As mentioned, as an example, a completion can include the packer 520 disposed within a bore defined by the casing 505 to isolate an upper low pressure zone associated with the pump 510, the electric motor 514 and the electric motor cooling sub-system from a lower zone associated with a receiving formation. As an example, an ESP system can include an ESP and various other components. For example, an ESP system can include the conduit 509, the pump 510, the inlet 512, a motor protector 513 (e.g., including dielectric oil, etc.), the electric motor 514, and a support 515 (e.g., a support conduit, optionally including one or more pieces of equipment, etc.) installed in a well where various components allow the ESP to operate to pump injection water into the receiving formation (e.g., at an injection region or regions) at a desired pressure and flow rate.

[0057] In the example of Fig. 5, a path may exist such that a tool, wireline, etc., may be disposed along at least a portion of the trajectory, for example, within tubing. The side pocket mandrel 507 may include a main bore through which a tool may be run while a side bore can seat the flow regulator valve 525 that can regulate flow to, for example, the capillary tubing 523. As an example, the flow regulator valve 525 may be adjustable and/or replaceable (e.g., via running a tool, etc.).

[0058] In the example of Fig. 5, the Y-tool 508 may be implemented to axially offset the pump 510, the electric motor 514, etc. Depending on arrangement and control of components located above (e.g., uphole) from the Y-tool 508, flow may be directed in a substantially U-shaped path (e.g., a “U-turn” from upwards via the pump 510 to downward via a bore of the Y-tool 508; see also, e.g., Fig. 3). As an example, one or more components of the system 500 may be replaced, adjusted, controlled, etc., such that the pump 510 may be utilized to direct fluid from a downhole region toward the surface (e.g., via tubing).

[0059] The system 500 of Fig. 5 may allow for flexibility in operations. For example, such a system may be optionally installed at a relatively shallow depth in an injection well, for example, to help reduce environmental impact. As an example, an electric submersible pump can be disposed in a well with the purpose to inject water in a formation for disposal, pressure maintenance, etc.

[0060] The system of Fig. 5 may be implemented in a system such as, for example, the system 300 of Fig. 3. As an example, various features of the ESP system 410 of Fig. 4 may be included in a system such as the system 500 of Fig. 5.

[0061] As an example, in the system 500, the power control units 501 and 502 may be, for example, a variable speed drive (e.g., or optionally a fixed speed drive) and a current transformer 502, respectively. As an example, the well head assembly 503 can include various components that can allow for coupling to a supply conduit or supply conduits (e.g., to supply water and/or other fluid). As shown in Fig. 5, the tubing 506 can be employed to run and, for example, at least in part support the electric submersible pump in the well at a desired depth. The power cable 522 is operatively coupled to at least one of the power control units 501 and 502 and can be used to provide the energy to the electric motor 514, which can include a shaft that transmit torque to the pump 510. As an example, the electric motor 514 can be a rotary motor. As an example, an ESP may include a reciprocating electric motor (e.g., with a shaft that is driven linearly in a reciprocating manner) that is operatively coupled to a pump, optionally via a gear-box that may transform linear motion to rotary motion.

[0062] Fig. 6 shows an example of a portion of the system 500 and an approximate cross-sectional view along a line A-A, which includes the bypass tubing 511, the electric motor 514 and the capillary tubing 523 (e.g., which may be offset from an axis of the bypass tubing).

[0063] As an example, a portion of the system 500 may be assembled via off-the-shelf components. For example, the Y-tool 508 may be an off-the-shelf tool that is suitable for use in a system that includes a series of ESPs. As an example, such a tool may be used to couple an ESP substantially parallel to tubing and include a valve that is actuated via a pressure differential such that pressure generated via the ESP causes a flapper of the valve to effectively close an opening of the tool that is in fluid communication with the tubing. In such a manner, fluid pumped by the ESP may be directed upwards via the tool rather than downwards via the tubing.

[0064] As an example, a specialized assembly for cooling an electric motor may include the capillary tubing that extends from a branch, at one end, to a location proximate to the electric motor, at another end. As mentioned, a branch may be formed via a mandrel such as a side pocket mandrel that can include a valve that can regulate flow of fluid from a main bore of the side pocket mandrel to a side bore that is in fluid communication with capillary tubing (e.g., tubing of suitable diameter and length).

[0065] As an example, a system may optionally include a valve coupled to the bypass tubing, a valve coupled to a coupling 516, etc., where such a valve may direct fluid for cooling the electric motor 514 (e.g., at an axial location of the electric motor 514 and/or below the electric motor 514).

[0066] As to Fig. 6, the following description references various components, features, etc., generally from top to bottom. As shown in the example of Fig. 6, the wireline compatible check valve or blanking plug 524 can be located above the Y-tool 508 to isolate an upper section of the tubing 506 from a lower section of the tubing 506, for example, to avoid having the upper section of the tubing 506 at a high pressure. As an example, the check valve or blanking plug 524 may be operated and/or removed to allow changing of the flow regulator valve 525 as disposed in the side pocket mandrel 507 and also, for example, to provide free access to one or more injection regions of a formation (e.g., portion below the packer 520). As shown in the example of Fig. 6, the side pocket mandrel 507 is coupled to the tubing 506.

[0067] In the example of Fig. 6, the flow regulator valve 525 can be implemented to provide a path to recirculate a portion of the water pumped by the electric submersible pump 510. In the example of Fig. 6, the capillary tube 523 is connected to the side pocket mandrel 507 (e.g., and/or the flow regulator valve 525) to discharge the recirculating portion of water at a location or locations that can be axially even with and/or below the electric motor 514 for providing water that can help to cool the electric motor 514. Thus, as shown, a portion of the water pumped by the pump 510 can be recirculated to a location such that it can act as a heat transfer medium that can receive heat energy and carry heat energy away from the electric motor 514 (e.g., and optionally one or more other components). As an example, such cooling water may reenter the pump 510 via the inlet 512.

[0068] As shown in Fig. 6, the Y-tool 508 can include interior passages that can change a direction of pumped water and that can direct at least a portion of the pumped water through the bypass tubing 511 to be injected into one or more regions of a formation (see, e.g., the region 521 of the formation of Fig. 5). In the example of Fig. 6, the pump can discharge via the conduit 509, which may be connected to the Y-Tool 508. As mentioned, a support 515, which may be a gauge, a conduit, etc., may be coupled to a coupling 516. As an example, where the support 515 is a gauge, it may be in fluid communication with fluid that flows in the coupling 516 and/or positioned to measure one or more of temperature, pressure, etc., as may be associated with fluid that flows in the coupling 516 (e.g., pumped injection water, etc.). Such a configuration with associated tools can allow for monitoring discharge pressure of the pump 510, at least for a portion of its discharge that is directed to the coupling 516 via the bypass tubing 511.

[0069] As an example, one or more sensors may be included in the system 500 and positioned to measure temperature, pressure, etc. of fluid such as fluid that exits the capillary tubing 523. As an example, a gauge may be coupled to the electric motor 514 and may be utilized to measure temperature, pressure, etc. in a space or spaces (e.g., in the coupling 516, in a cooling water space, etc.).

[0070] As an example, the pump 510 may include a number of stages to develop enough discharge pressure to inject the water to one or more regions of a formation with a desired pressure and/or a desired flow. As an example, a stage may be an impeller stage (e.g., or an impeller and diffuser stage).

[0071] As shown, in the example of Fig. 6, water inside the annular space 504 (see, e.g., large open headed arrow) can enter the pump 510 through the inlet 512, which is located at a desired depth such that hydrostatic pressure can be sufficient to feed the pump 510 (e.g., also considering draw pressure generated by operating the pump 510). For example, an ESP may be located at a depth where the depth is determined at least in part via a pressure head at an inlet of a pump of the ESP.

[0072] As shown, the system 500 can include the protector 513 (e.g., or protectors) where configuration thereof can depend on one or more mechanical, chemical, physical, etc., conditions of the well and, for example, one or more characteristics of the electric motor 514. The electric motor 514 can provide horsepower as desired by for deliver to the pump 510 (e.g., via a shaft).

[0073] As an example, an electric motor cooling sub-system can be provided at least in part by the flow regulator valve 524 and capillary tubing 523, which operatively connects with the side pocket mandrel 507 to convey recirculating water to be discharged even with and/or below the electric motor 514.

[0074] As mentioned with respect to the example of Fig. 5, the electric motor 514 can be energized via one or more of the surface power units 501 and 502 through the power cable 522. Such a cable (or cables) may be dimensioned based on the electric motor 514, pumping demands of the pump 510, etc. As an example, the electric motor 514 can include a pothead section where the power cable 522 may operatively couple to the electric motor 514. As an example, one or more motor lead extensions (MLEs) may be employed to couple a power cable or power cables to the electric motor 514.

[0075] As mentioned, the support 515 may be or include at least one sensor. As shown in Fig. 6, the support 515 can be operatively coupled to the electric motor 514, for example, to receive power and/or to communication information via the power cable 522. As an example, circuitry of the support 515 may be powered at least in part via an electrical connection to a WYE point of a multiphase electric motor. As an example, the support 515 and/or the electric motor 514 may include one or more sensors. As an example, a sensor may be a temperature sensor, a pressure sensor, a flow sensor, or another type of sensor. As an example, sensed information may be communicated to one or more surface units such as, for example, one or more of the power units 501 and 502, which, in turn, may provide for adjusting operation of the electric motor 514 and/or one or more other components of the system 500. As an example, the support 515 can be installed at the motor base of the electric motor 514 and can measure, for example, pressure and/or temperature as variables for monitoring and controlling an electric submersible pump.

[0076] As an example, a nipple seat may allow for accommodation of a wireline compatible check valve or blanking plug as the check valve or blanking plug 524, for example, which may be retrieved or installed with slick line equipment. Such a wireline compatible check valve or blanking plug can provide for testing tubing integrity or one or more other functions.

[0077] As an example, the packer 520 may be set in the casing 505 and function to define, separate and seal low and high pressure zones. The packer 520 may be installed close to the injection region 521 of a formation, for example, to reduce the casing area exposed to high pressure. As an example, operations of running and setting the packer 520 may be achieved by using wireline unit. As an example, a stinger 519 can be part of the injection column and include a sealing unit connected in the packer seal bore of the packer 520. When the stinger 519 is connected to the packer seal bore of the packer 520 a leak test may be performed to check the integrity of the seal between the annular space 504 and the tubing 506.

As an example, the stinger 519 may allow for the pulling of the electric submersible pump for maintenance without removing the packer 520.

[0078] Fig. 7 shows an example of a system 700 that includes a plug 705 (e.g., optionally an adjustable plug), a side pocket mandrel 710, a valve 715, a Y-tool 720 and a recirculation conduit 730 (e.g., capillary tubing, etc.). Such a system, which may be a sub-system in another system, can include an electric submersible pump mount 724, a tubing mount 726 and a recirculation conduit mount 716. For example, the Y-tool 720 can include the tubing mount 726 and the electric submersible pump mount 724 and the side pocket mandrel 710 and/or the valve 715 can include the recirculation conduit mount 716.

[0079] As shown in the example of Fig. 7, the Y-tool 720 can include a single bore at one end and, for example, a pair of bores at another end. As shown, one bore of the pair of bores of the Y-tool 720 can receive fluid and such fluid may be directed in part to the other bore of the pair of bores of the Y-tool 720 and directed in part to the bore at the other end of the Y-tool, which may then flow into a bore of the side pocket mandrel 710 (e.g., directly or via an intermediate tubing, coupling, etc.). As the plug 705 may effectively block fluid flow upwardly, fluid in the side pocket mandrel 710 may flow via the valve 715 to the recirculation conduit 730. As an example, the angle of orientation of the side pocket of the side pocket mandrel 710 may be oriented such that the recirculation conduit can pass in a straight line axially past an outer surface of the Y-tool 720. As an example, the recirculation conduit 730 may include a bend or bends such that it can extend past an outer surface of the Y-tool 720. As an example, the system 700 of Fig. 7 may be referred to as a header or a header assembly or a header system. For example, a header may function to direct flow of fluid to a plurality of paths, optionally in an adjustable or controllable manner (e.g., via one or more valves). In the example of Fig. 7, the Y-tool 720 is shown as including a flapper valve 722, which may be fixed or otherwise adjusted, controlled, etc., for purposes of recirculation of fluid to cool an electric motor of an ESP.

[0080] While the system 700 of Fig. 7 includes the side pocket mandrel 710, such a system may include another type of mandrel and valve arrangement. As an example, a mandrel can be a tubular component or an assembly that includes a tubular component. As an example, a mandrel can include or be operatively coupled to a valve, for example, to regulate flow of fluid to a recirculation conduit that can direct fluid for cooling an electric motor of an ESP.

[0081] Fig. 8 shows an example of a method 810 that includes a flow block 814 for flowing water into an upper portion of a well; a reception block 818 for receiving the water at an intake (e.g., an inlet) of an electric submersible pump disposed in the well; a pump block 822 for pumping the water toward the upper portion of the well via the electric submersible pump; a reception block 826 for receiving the pumped water at a header; a direction block 830 for directing a portion of the water from the header to a recirculation conduit that includes an opening proximate to a motor of the electric submersible pump and directing another portion of the water from the header to tubing that includes an opening sealed from the intake of the pump. Such a method may include, for example, cooling the motor via the portion of the water directed to the recirculation conduit (e.g., removing heat energy from the motor by transferring heat energy from the motor to the water).

[0082] As an example, a header can include a Y-tool and a side pocket mandrel that includes a valve where the side pocket mandrel may receive fluid via an opening of the Y-tool and direct at least a portion of the received fluid via the valve to a recirculation conduit (see, e.g., Figs. 5, 6 and 7). As an example, a header can include a Y-tool that includes an additional bore that can direct fluid to a recirculation conduit (e.g., a side axis bore that extends outwardly from a Y-shaped portion of a Y-tool). As an example, a header can include a branched coupling operatively coupled to a Y-tool where the branched coupling can direct fluid to a recirculation conduit (see, e.g., the header 371 of Fig. 3).

[0083] As an example, a method can include flowing water into an upper portion of a well; receiving the water at an intake (e.g., an inlet) of an electric submersible pump disposed in the well; pumping the water toward the upper portion of the well via the electric submersible pump; receiving the pumped water at a header; and directing a portion of the water from the header to a recirculation conduit that includes an opening proximate to a motor of the electric submersible pump and directing another portion of the water from the header to tubing that includes an opening sealed from the intake of the pump. Such a method may include regulating the portions of water via one or more flow regulator valves.

[0084] As an example, an electric submersible pump may be operatively coupled to a side pocket mandrel. In such an example, the side pocket mandrel can include a header or be part of a header.

[0085] As an example, a method may include controlling temperature of a motor of a pump at least in part via a portion of water directed to a recirculation conduit.

[0086] As an example, a method can include supplying water via a low pressure supply line. Such water may be, for example, water separated from a mixture of oil and water. A method may include separating water from a mixture of oil and water.

[0087] As an example, a method may include controlling an electric submersible pump and, for example, controlling a regulator valve that regulates at least the portion of pumped water directed to a conduit (e.g., a recirculation conduit).

[0088] As an example, a system can include a header that includes a side pocket mandrel, an electric submersible pump mount, a tubing mount and a recirculation conduit mount. Such a system may include tubing operatively coupled to the tubing mount; a recirculation conduit operatively coupled to the recirculation conduit mount and/or an electric submersible pump operatively coupled to the electric submersible pump mount. As an example, such a system may include tubing operatively coupled to the tubing mount, a recirculation conduit operatively coupled to the recirculation conduit mount and an electric submersible pump operatively coupled to the electric submersible pump mount where the recirculation conduit includes an opening proximate to a motor of the electric submersible pump.

[0089] As an example, a system can include a header that includes a mandrel, a valve, an electric submersible pump mount, a tubing mount and a recirculation conduit mount; tubing operatively coupled to the tubing mount; a recirculation conduit operatively coupled to the recirculation conduit mount where the valve controls flow of fluid to the recirculation conduit; and an electric submersible pump operatively coupled to the electric submersible pump mount where the electric submersible pump includes, in an axial order with respect to an axis of the electric submersible pump, a pump, a pump inlet and an electric motor and where the recirculation conduit extends axially past the pump inlet to an opening of the recirculation conduit that is located axially even with or axially past the electric motor.

In such an example, the mandrel can be a side pocket mandrel that may seat the valve.

[0090] As an example, tubing can include a bore that defines a tubing axis where, for example, the tubing axis is substantially parallel to an axis of an electric submersible pump. For example, such axes may be about plus or minus within about 20 degrees over their axial lengths. As an example, a recirculation conduit can include a bore that defines a recirculation conduit axis where, for example, the recirculation conduit axis is substantially parallel to the axis of the electric submersible pump. For example, such axes may be about plus or minus within about 20 degrees over their axial lengths.

[0091] As an example, a system can include a gauge operatively coupled to an electric submersible pump where the gauge includes at least one sensor. In such an example, the gauge may provide for sensing one or more of pressure, temperature, vibration, flow, flow rate, etc.

[0092] Although only a few examples have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the examples. Accordingly, all such modifications are intended to be included within the scope of this disclosure as defined in the following claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Thus, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface, in the environment of fastening wooden parts, a nail and a screw may be equivalent structures. It is the express intention of the applicant not to invoke 35 U.S.C. § 112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words “means for” together with an associated function.

CLAIMS

What is claimed is:

1. A method comprising:

flowing water into an upper portion of a well;

receiving the water at an intake of an electric submersible pump disposed in the well;

pumping the water toward the upper portion of the well via the electric submersible pump;

receiving the pumped water at a header; and

directing a portion of the water from the header to a recirculation conduit that comprises an opening proximate to a motor of the electric submersible pump and directing another portion of the water from the header to tubing that comprises an opening sealed from the intake of the pump.

2. The method of claim 1 comprising regulating the portions of water via one or more flow regulator valves.

3. The method of claim 1 wherein the electric submersible pump is operatively coupled to a side pocket mandrel.

4. The method of claim 3 wherein the header comprises the side pocket mandrel.

5. The method of claim 1 comprising controlling temperature of the motor at least in part via the portion of water directed to the recirculation conduit.

6. The method of claim 1 comprising supplying the water via a low pressure supply line.

7. The method of claim 6 wherein the water comprises water separated from a mixture of oil and water.

8. The method of claim 7 further comprising separating the water from the mixture of oil and water.

9. The method of claim 1 further comprising controlling the electric submersible pump.

10. The method of claim 9 further comprising controlling a regulator valve that regulates at least the portion of the pumped water directed to the conduit.

11. A system comprising:

a header that comprises side pocket mandrel, an electric submersible pump mount, a tubing mount and a recirculation conduit mount.

12. The system of claim 11 comprising tubing operatively coupled to the tubing mount.

13. The system of claim 11 comprising a recirculation conduit operatively coupled to the recirculation conduit mount.

14. The system of claim 11 comprising an electric submersible pump operatively coupled to the electric submersible pump mount.

15. The system of claim 11 comprising tubing operatively coupled to the tubing mount, a recirculation conduit operatively coupled to the recirculation conduit mount and an electric submersible pump operatively coupled to the electric submersible pump mount wherein the recirculation conduit comprises an opening proximate to a motor of the electric submersible pump.

16. A system comprising:

a header that comprises a mandrel, a valve, an electric submersible pump mount, a tubing mount and a recirculation conduit mount;

tubing operatively coupled to the tubing mount;

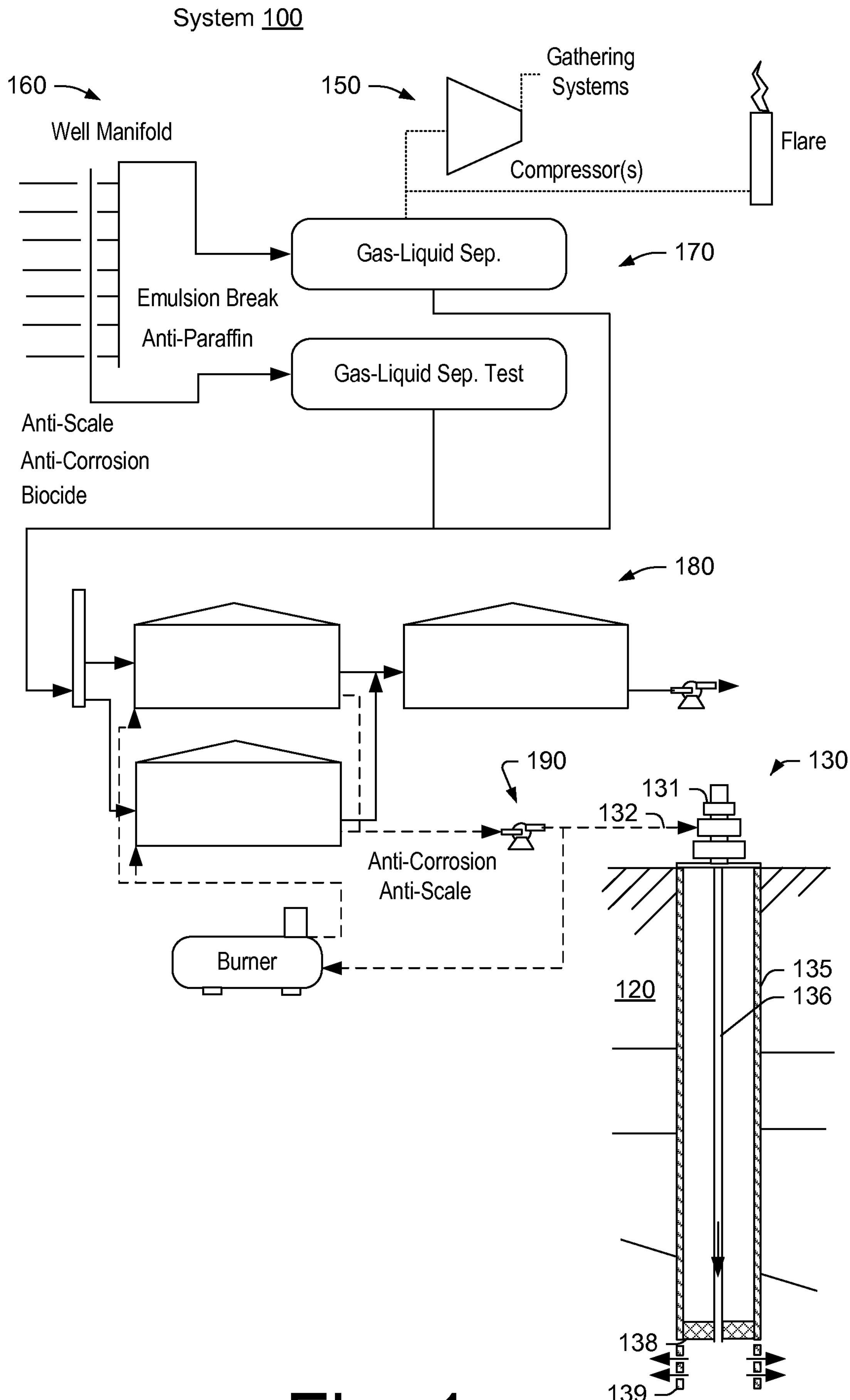
a recirculation conduit operatively coupled to the recirculation conduit mount wherein the valve controls flow of fluid to the recirculation conduit; and an electric submersible pump operatively coupled to the electric submersible pump mount wherein the electric submersible pump comprises, in an axial order with respect to an axis of the electric submersible pump, a pump, a pump inlet and an electric motor and wherein the recirculation conduit extends axially past the pump inlet to an opening of the recirculation conduit that is located axially even with or axially past the electric motor.

17. The system of claim 16 wherein the mandrel comprises a side pocket mandrel that seats the valve.

18. The system of claim 16 wherein the tubing comprises a bore that defines a tubing axis and wherein the tubing axis is substantially parallel to the axis of the electric submersible pump.

19. The system of claim 16 wherein the recirculation conduit comprises a bore that defines a recirculation conduit axis and wherein the recirculation conduit axis is substantially parallel to the axis of the electric submersible pump.

20. The system of claim 16 comprising a gauge operatively coupled to the electric submersible pump wherein the gauge comprises at least one sensor.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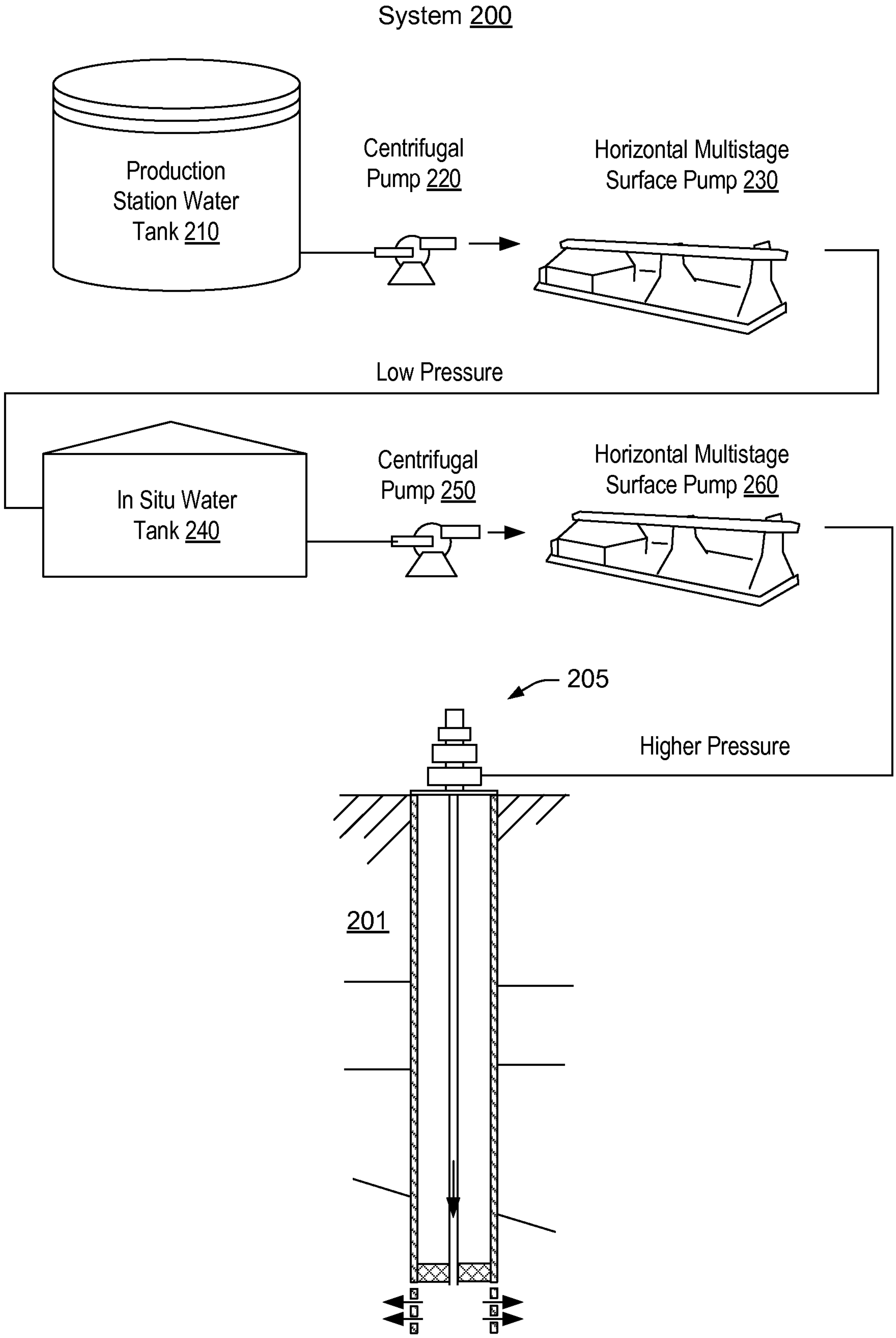
160
Well Manifold
150
Gathering Systems
Flare
Compressor(s)
Gas-Liquid Sep.
170
Emulsion Break
Anti-Paraffin
Gas-Liquid Sep. Test
Anti-Scale
Anti-Corrosion
Biocide
180
190
130
131
132
Anti-Corrosion
Anti-Scale
Burner
120
135
136
138
139

Fig. 1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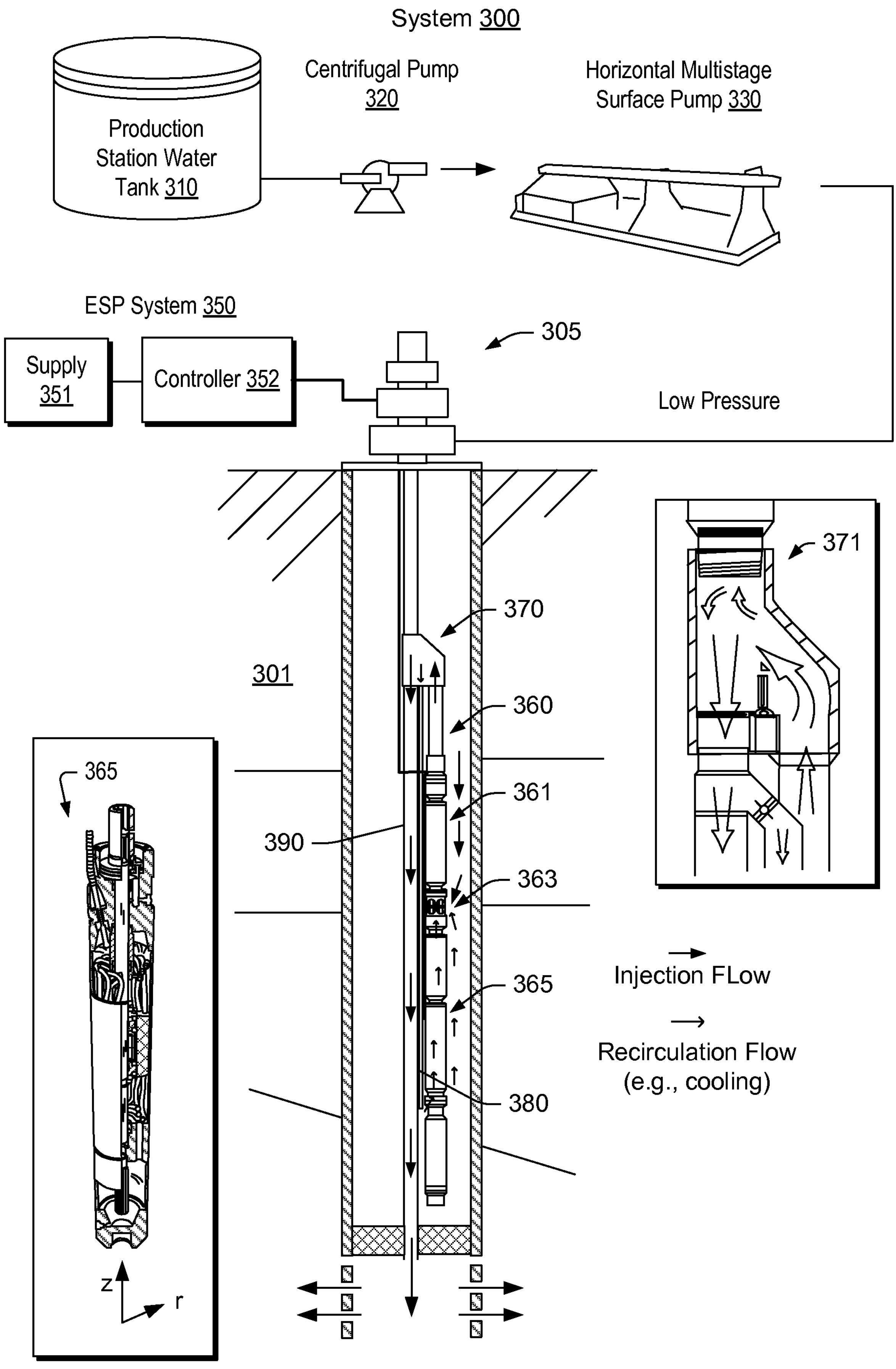
Production
Station Water
Tank 210
Centrifugal
Pump 220
Horizontal Multistage
Surface Pump 230
Low Pressure
In Situ Water
Tank 240
Centrifugal
Pump 250
Horizontal Multistage
Surface Pump 260
205
Higher Pressure
201

Fig. 2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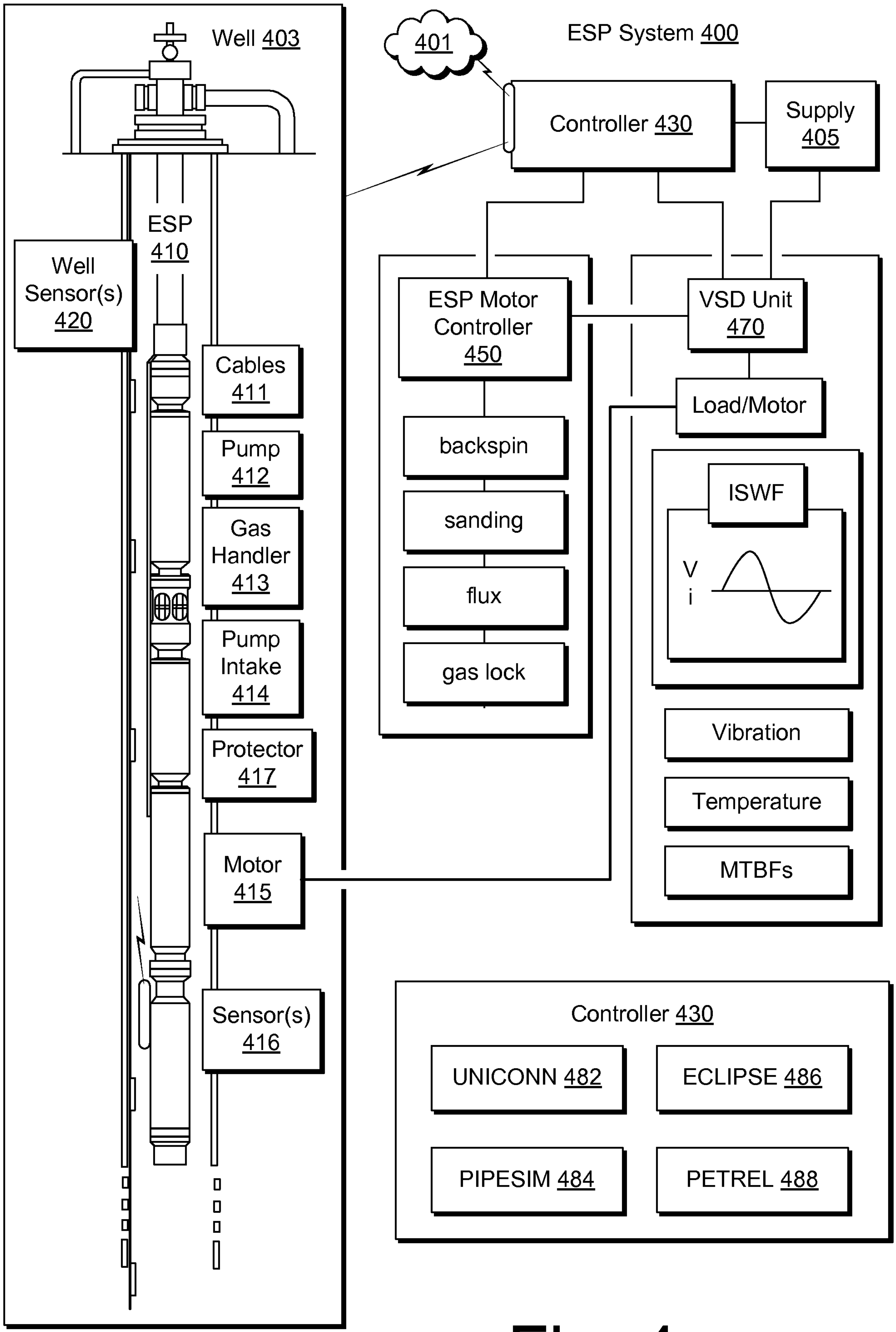
Production
Station Water
Tank 310
Centrifugal Pump
320
Horizontal Multistage
Surface Pump 330
ESP System 350
Supply
351
Controller 352
305
Low Pressure
371
370
301
360
365
361
390
363
365
Injection FLow
Recirculation Flow
(e.g., cooling)
380
z
r

Fig. 3


Well 403
ESP 410
Well Sensor(s) 420
Cables 411
Pump 412
Gas Handler 413
Pump Intake 414
Protector 417
Motor 415
Sensor(s) 416
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ESP System 400
Controller 430
Supply 405
ESP Motor Controller 450
backspin
sanding
flux
gas lock
VSD Unit 470
Load/Motor
ISWF
V
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Vibration
Temperature
MTBFs
Controller 430
UNICONN 482
ECLIPSE 486
PIPESIM 484
PETREL 488

Fig. 4

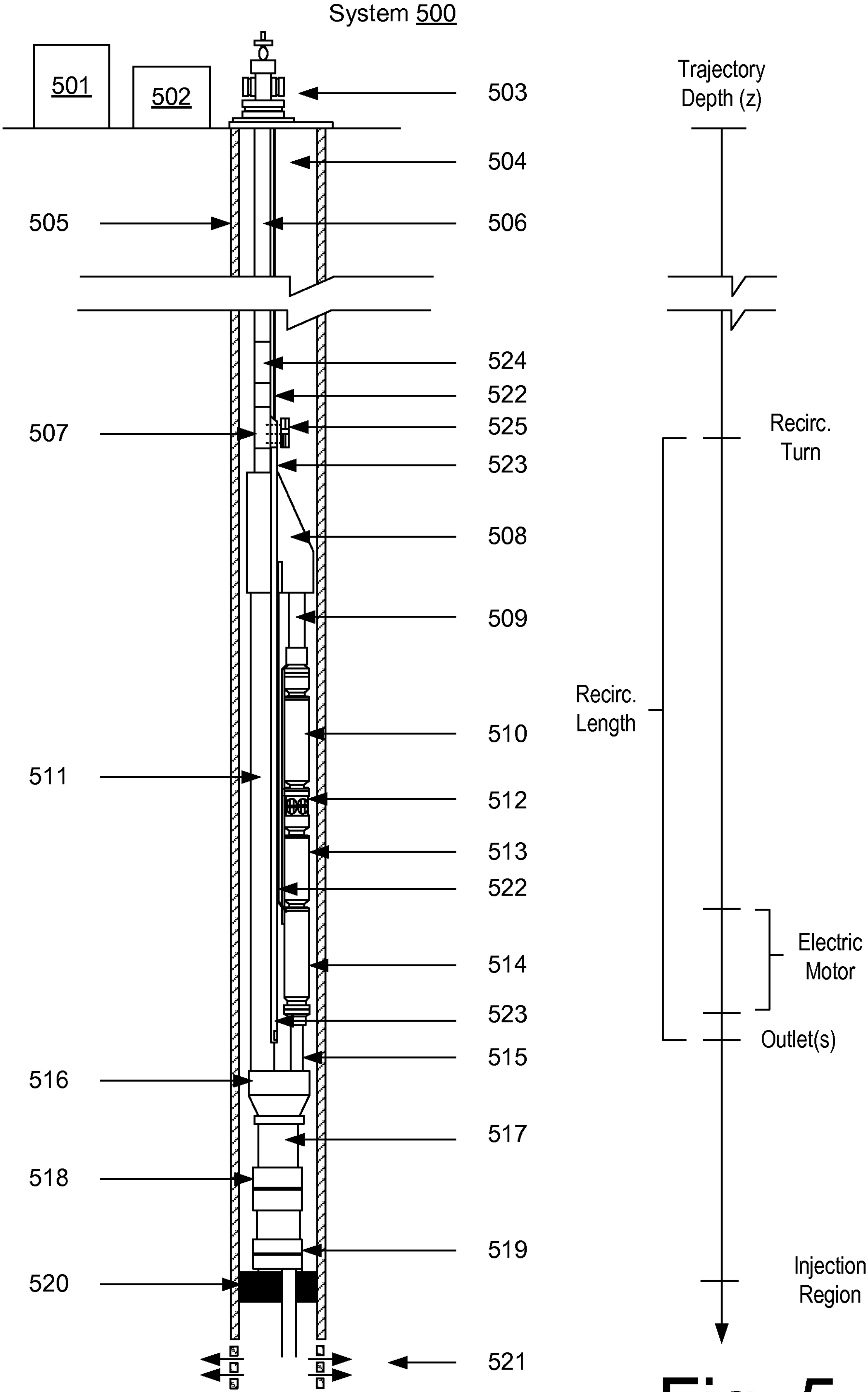
System 500
501
502
503
504
505
506
524
522
525
507
523
508
509
510
511
512
513
522
514
523
515
516
517
518
519
520
521
Trajectory Depth (z)
Recirc. Turn
Recirc. Length
Electric Motor
Outlet(s)
Injection Region

Fig. 5

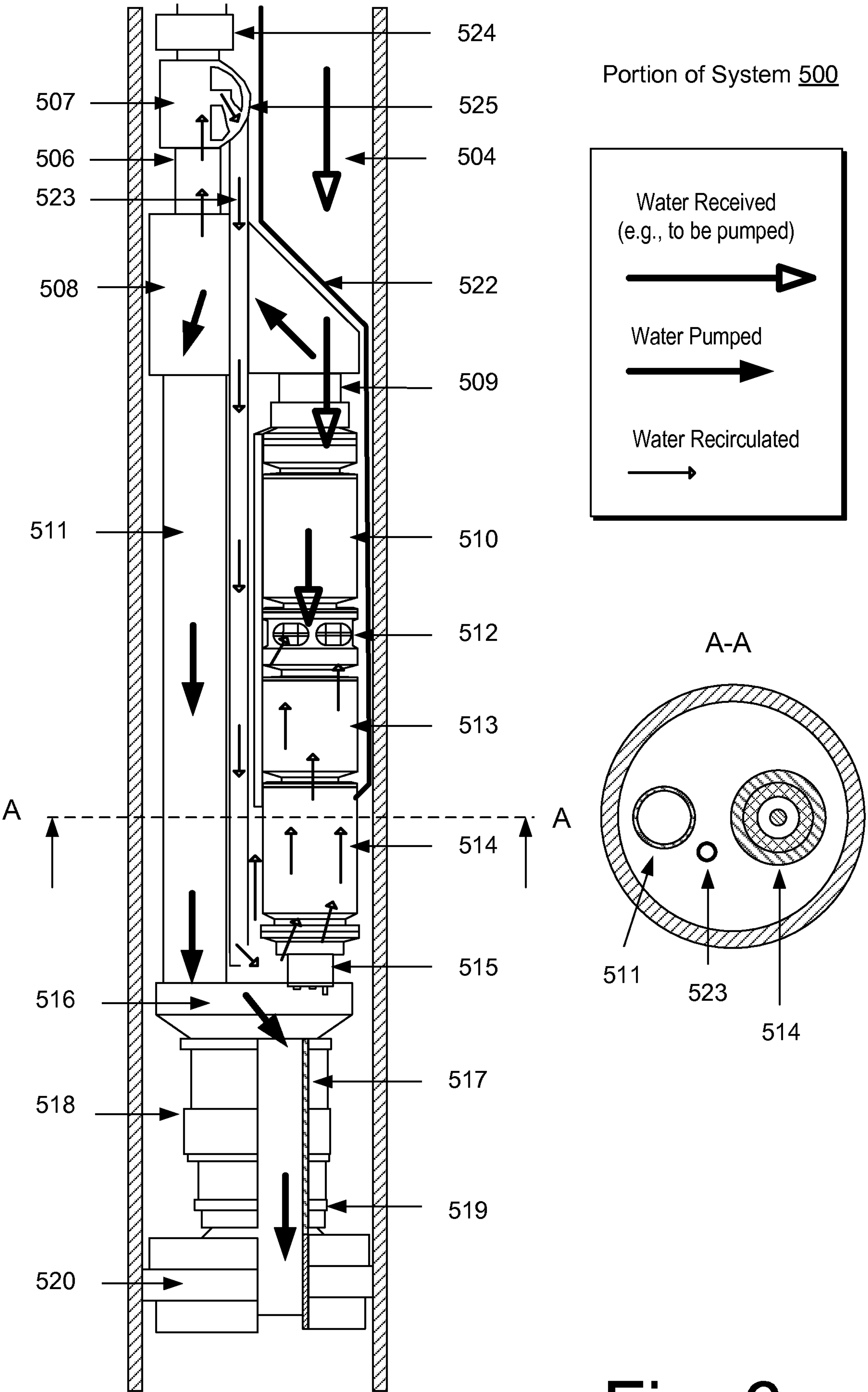
Portion of System 500
Water Received
(e.g., to be pumped)
Water Pumped
Water Recirculated
524
525
507
506
504
523
508
522
509
511
510
512
513
A
A
514
515
516
517
518
519
520
A-A
511
523
514

Fig. 6

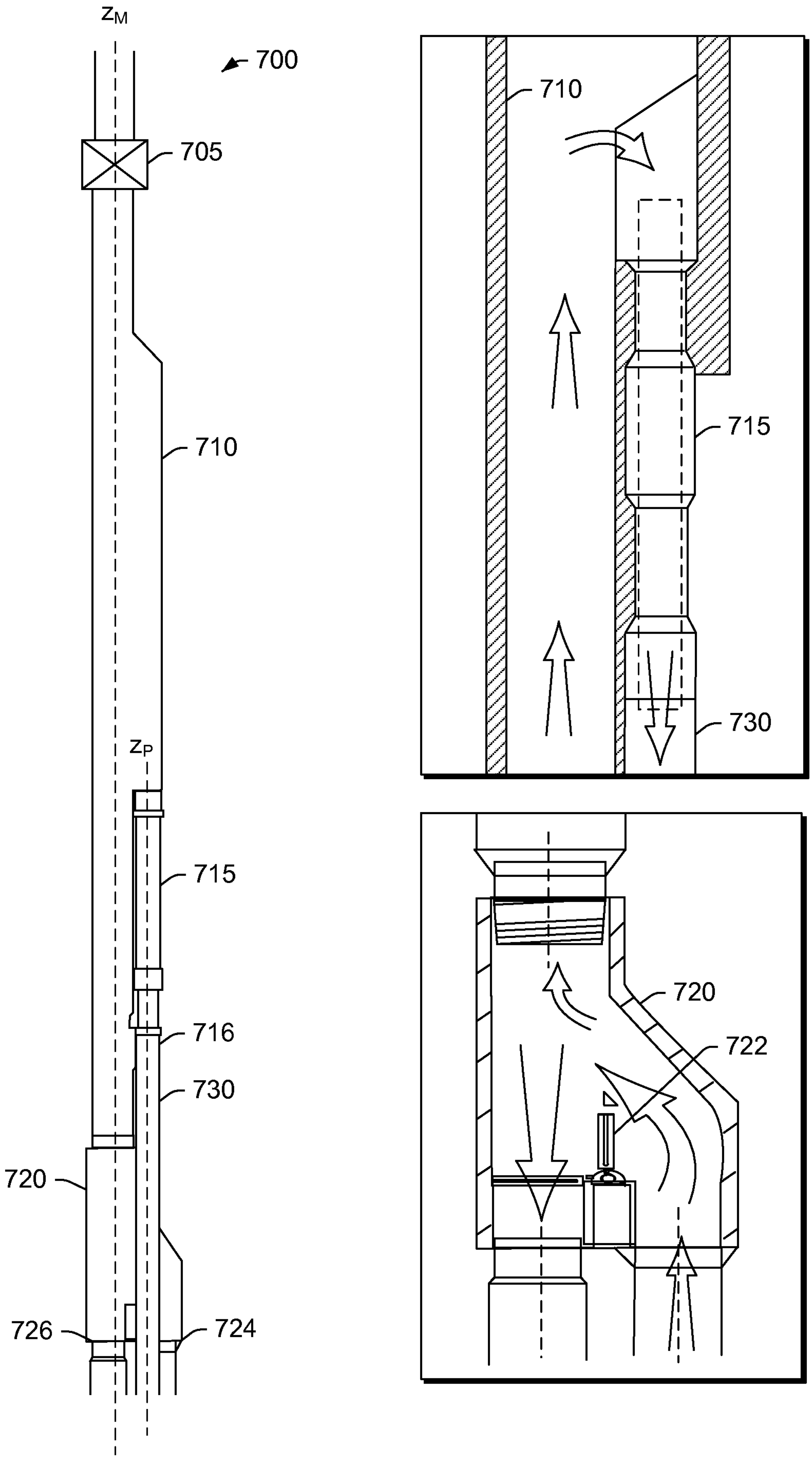

Fig. 7

Method 810

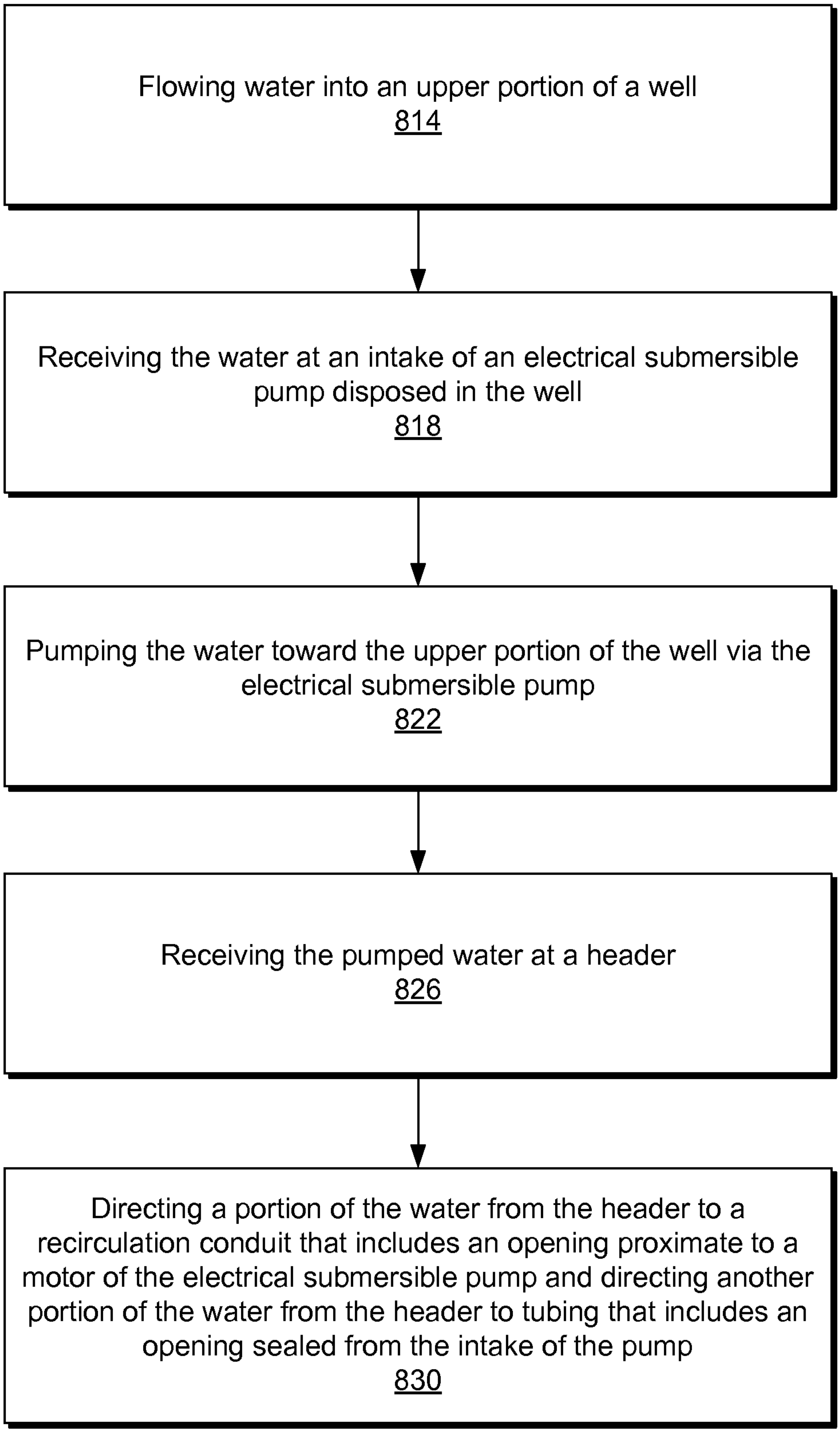

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/048779

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/16(2006.01)i, E21B 43/20(2006.01)i, E21B 43/26(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 43/16; E21B 43/12; G05D 7/00; E21B 43/20; E21B 43/00; E21B 34/10; E21B 43/26

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: injection, water, electric submersible pump, well, header, side pocket mandrel, recirculation conduit, motor, tubing, mount, flow regulator valve and supply line

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009-0159262 A1 (GAY et al.) 25 June 2009 See paragraphs [0013]-[0024] and figures 1-3B.	11-15
Y		1-10,16-20
Y	US 2009-0211755 A1 (DYER et al.) 27 August 2009 See paragraphs [0015]-[0029] and figures 1-2.	1-10,16-20
A	US 2014-0000864 A1 (FIELDER, III et al.) 02 January 2014 See paragraphs [0012]-[0052] and figures 1-4.	1-20
A	US 2013-0175030 A1 (IGE et al.) 11 July 2013 See paragraphs [0019]-[0150] and figures 1-14.	1-20
A	US 2007-0012454 A1 (ROSS et al.) 18 January 2007 See paragraphs [0017]-[0028] 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:
"A" document defining the general state of the art which is not considered to be of particular relevance
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Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
RHEE, Jun Ho
Telephone No. +82-42-481-8288

INTERNATIONAL SEARCH REPORT

Information on patent family members

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