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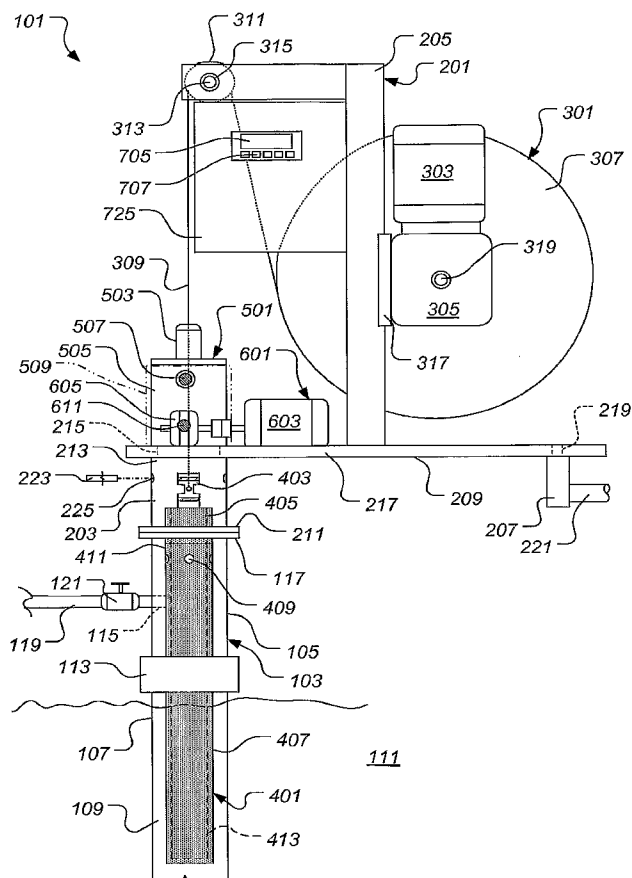
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(54) Title: FLUID LIFT SYSTEM



(57) Abstract: A fluid lift system includes a canister defining a cavity for lifting fluid and an orifice at an upper portion of the canister extending to the cavity, a reel, and a cable operably associated with the reel and the canister. The fluid lift system further includes a motor operatively associated with the reel, the motor operable to raise and lower the canister and a head housing defining a bore in which the upper portion of the canister is sealingly received, the head housing defining a port extending into the cavity. The fluid lift system further includes a pump in fluid communication with the head housing, the pump operable to vacuum lifted fluid from the cavity of the canister through the orifice and the port and a control system for operating the motor and the pump.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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FLUID LIFT SYSTEM

Cross-Reference to Related Applications

This application claims the benefit of U.S. Provisional Application No. 60/759,382, filed 17 January 2006, entitled "Fluid Lift System," which is incorporated
5 herein by reference for all purposes.

Technical Field

The present invention relates to fluid lift systems. In particular, the present invention relates to systems for lifting fluids from wells.

Description of the Prior Art

10 Marginally producing wells, such as oil wells, are often left abandoned because the costs to conventionally produce fluids from the wells outweigh the monetary return for the fluids. Fluid lift systems have been devised in an attempt to provide a lower-cost way to lift fluids from marginally producing wells. However, these conventional systems have many problems. For example, most conventional
15 fluid lift systems allow gases from within the wells to be vented to the atmosphere. Moreover, some conventional fluid lift systems use ambient air to urge fluids from the fluid lift system, presenting a potentially hazardous or explosive situation when the fluid being lifted contains hydrocarbons. Furthermore, these conventional lift systems fail to adequately contain the fluids being lifted from wells, which often
20 results in damage to the ecology.

Most conventional fluid lift systems are complex and require precise adjustment and tolerances for proper operation. Some conventional fluid lift systems "swab" wells, such that the wells are left substantially dry. This is undesirable, because swabbing wells is unacceptable to most governmental regulatory agencies.
25 When used in oil wells, conventional fluid lift systems often lift oil and water, because the location of the oil-water interface is not known. In addition, many conventional fluid lift systems lack a means for proper attachment to well casings. This is a

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problem, because most governmental regulatory agencies object to portable, i.e. trailer-mounted, fluid lift systems.

Therefore, while fluid lift systems are well known in the art, considerable room for improvement remains.

5 Brief Description of the Drawings

The novel features believed characteristic of the invention are set forth in the appended claims. However, the invention itself, as well as a preferred mode of use, and further objectives and advantages thereof, will best be understood by reference to the following detailed description when read in conjunction with the accompanying
10 drawings, wherein:

Figure 1 is a stylized, side, elevational view of an illustrative embodiment of a fluid lift system according to the present invention;

Figure 2 is an enlarged, side, cross-sectional view of a head assembly and a portion of a canister assembly of the fluid lift system of Figure 1;

15 Figure 3 is a stylized, block diagram representing a pumping assembly and certain sensors of the fluid lift system of Figure 1;

Figure 4 is a stylized, block diagram representing a control system of the fluid lift system of Figure 1;

20 Figure 5 is a stylized, partial cross-sectional view of a load-indicating shaft and a signal conditioner of the fluid lift system of Figure 1;

Figure 6 is a stylized, top, plan view of a load sensor of the load-indicating shaft of Figure 5, shown in an unrolled condition;

25 Figures 7A-7D are stylized, graphical representations of the canister assembly of the fluid lift system of Figure 1, illustrating one particular method of operating the fluid lift system of Figure 1;

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Figure 8 is a stylized, block diagram representing a solar energy system of the fluid lift system of Figure 1;

Figure 9 is a stylized, partial cross-sectional view of an alternative, illustrative embodiment of a portion of a fluid lift system, according to the present invention; .

5 Figure 10 is a stylized, top, plan view of an alternative, illustrative embodiment of a portion of a fluid lift system, according to the present invention.;

Figure 11 is a stylized, partial cross-sectional view of an alternative, illustrative embodiment of a portion of a fluid lift system, according to the present invention;

10 Figure 12 is a stylized, cross-sectional view of an alternative packing set according to the present invention;

Figure 13 is a stylized, partial cross-sectional view of an alternative embodiment of a load-indicating shaft including a signal conditioner of the fluid lift system of Figure 1;

15 Figure 14 is a stylized, side, elevational view of a portion of an alternative embodiment of a fluid lift system including a traveling sheave according to the present invention;

Figure 15 is a front, elevational view of the traveling sheave of Figure 14; and

Figure 16 is a partial cross-sectional view of an illustrative embodiment of a swivel coupling a cable and a canister of the present invention.

20 While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all
25 modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

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Description of the Preferred Embodiment

Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

The present invention represents a fluid lift system and a method of making, using, monitoring, servicing, and reporting from the fluid lift system. The fluid lift system of the present invention is particularly useful in lifting oil from oil wells having marginal production capabilities, often known as "stripper" wells. The fluid lift system of the present invention is also particularly useful in lifting oil from oil wells in which gases are trapped, as the fluid lift system allows the gases to be recovered rather than vented to the atmosphere.

In one aspect, a fluid lift system includes a canister defining a cavity for lifting fluid and an orifice at an upper portion of the canister extending to the cavity, a reel, and a cable operably associated with the reel and the canister. The fluid lift system further includes a motor operatively associated with the reel, the motor operable to raise and lower the canister and a head housing defining a bore in which the upper portion of the canister is sealingly received, the head housing defining a port extending into the cavity. The fluid lift system further includes a pump in fluid communication with the head housing, the pump operable to vacuum lift fluid from the cavity of the canister through the orifice and the port and a control system for operating the motor and the pump.

In another aspect a method of lifting fluid includes the steps of lowering a canister and detecting a depth at which contact is made between the canister and a

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top of a fluid pad. The method further includes the steps of lowering the canister to a predetermined depth below the top of the fluid pad and waiting for the canister to at least partially fill with fluid. The method further includes the steps of raising the canister and vacuuming the fluid from the canister.

5 Figure 1 depicts a side, elevational view of one particular embodiment of a fluid lift system 101 according to the present invention. As illustrated in the appended drawings, fluid lift system 101 comprises a well riser assembly 103, a frame assembly 201, a reel assembly 301, a canister assembly 401, a head assembly 501, a pumping assembly 601, a control system 701 (see Figure 4), and,
10 in at least one embodiment, a solar energy system 901 (see Figure 8). Each of these assemblies and systems will be described in detail below.

Well riser assembly 103 comprises a riser 105 coupled to an existing well casing 107. Well casing 107 is disposed within a well 109 drilled into ground 111. In one embodiment, riser 105 is coupled to well casing 107 via a threaded collar 113.
15 Riser 105 defines a gas outlet port 115 and comprises an upper flange 117. Gas outlet port 115 is adapted to interface with a gas recovery line 119 to provide fluid communication between a gas collection facility (not shown) and an interior of riser 105, so that gases drawn through well casing 107 are collected, rather than being merely vented to the atmosphere. In one embodiment, a valve 121 is coupled with
20 riser 105 and gas recovery line 119, such that gas recovery line 119 is in fluid communication with the interior of riser 105 via valve 121 when valve 121 is not closed. In one embodiment, riser 105 and threaded collar 113 comprise a stainless steel, or other corrosion-resistant materials, as fluids lifted from well 109 are often corrosive in nature.

25 Still referring to Figure 1, frame assembly 201 comprises a flange mount 203, a frame upright 205, and a recovery reservoir 207 attached to a base 209. Flange mount 203 comprises a lower flange 211 adapted to sealingly mate with upper flange 117 of riser 105. Preferably, a gasket (not shown) is disposed between upper flange 117 and lower flange 211. Moreover, upper flange 117 and lower flange 211 define
30 matching bolt-hole patterns, through which fasteners may be disposed to fixedly, but

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releasably, attach upper flange 117 to lower flange 211. An upper end 213 of flange mount 203 is attached to base 209, such that an interior of flange mount 203 is in fluid communication with an opening 215 defined by base 209. Frame upright 205 and base 209 support other elements of fluid lift system 101, as will be more fully described below. Preferably, base 209 comprises upright flanges 217 for retaining any fluids not contained during the fluid lifting process or during maintenance of fluid lift system 101. Recovery reservoir 207 is attached to base 209 and is in fluid communication with an opening 219 defined by base 209. Preferably, base 209 is sloped toward opening 219. Fluids in base 209 drain through opening 219 into recovery reservoir 207, where they are collected with fluids lifted from the well 109 via fluid recovery line 221. In one embodiment, one or all of the elements of frame assembly 201 comprise a stainless steel, or other corrosion-resistant materials, as fluids lifted from the well 109 are often corrosive in nature.

Reel assembly 301 comprises a reel motor 303, a gearbox 305, a reel 307, a cable 309, a sheave 311, a load-indicating shaft 313, a bearing 315, and a mounting flange 317. Reel motor 303 is mounted to and engaged with gearbox 305, which is mounted to frame upright 205 of frame assembly 201 via mounting flange 317. Preferably, reel motor 303 is a three-phase motor, capable of operating at various speeds. In one embodiment, reel motor 303 is a 3/4 horsepower, three-phase, variable speed motor. Gearbox 305, which is preferably a speed-reducing gearbox, includes an output shaft 319 to which reel 307 is mounted. In one embodiment, gearbox 305 is an 80:1 speed-reducing gearbox. Thus, when reel motor 303 is operated, the rotational motion of reel motor 303 is transmitted to reel 307 through gearbox 305, but at a reduced rotational speed. Cable 309 is attached at a first end to reel 307 and is wound thereon, such that cable 309 can be payed out from and retrieved onto reel 307. In one embodiment, reel 307 is sized to hold about 3,000 feet of cable 309. Cable 309 extends around sheave 311, which is rotationally mounted to frame upright 205 via load-indicating shaft 313 and bearing 315. Specifically, bearing 315 is fixedly mounted to frame upright 205 and to load-indicating shaft 313, providing a low-friction, rotational interface. Note that, in one embodiment, the position of load-indicating shaft 313 can be adjusted with respect to

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frame upright 205 along an axis generally perpendicular to the page plane of Figure 1. Bearing 315 allows load-indicating shaft 313, and thus sheave 311, to freely rotate with respect to frame upright 205.

As discussed above, cable 309 is attached at a first end to reel 307. Cable
5 309 is attached at a second end to canister assembly 401, as will be more fully described below. In one embodiment, cable 309 comprises a nylon-coated, galvanized, 7-19 stranded cable. Alternatively, cable 309 may comprise a stainless steel, stranded cable. Canister assembly 401 comprises a nose assembly 403, a coupling 405, and a canister 407. In a preferred embodiment, nose assembly 403 is
10 welded to coupling 405. Coupling 405 and canister 407 are adapted to be threadedly engaged with one another. Canister 407 defines one or more orifices 409 (only one labeled for clarity) near an upper end 411 of canister 407 and a cavity 413. Fluids that are to be lifted from well 109 flow from well 109 into cavity 413 via orifices 409. Orifices 409 are in fluid communication with cavity 413. In one embodiment,
15 canister 407 defines four orifices 409, each having a diameter of about 3/4 inch. In one embodiment, at least a portion of canister 407 is not rigid, *i.e.*, has some degree of flexibility.

When canister 407 is submerged in fluid within well 109, the fluid flows through orifices 409 into cavity 413 of canister 407. In one embodiment, cavity 413
20 has a volume of about 3.7 gallons and, thus, is appropriate for marginally-producing wells, such as stripper wells. The fluid is retained in cavity 413 until it is pumped therefrom, as will be described in greater detail below. In one embodiment, orifices 409 are adapted to receive a pin 223 for retaining canister assembly 401 in an upper position if cable 309 is to be detached therefrom. For example, pin 223 may be
25 inserted through openings 225, defined by flange mount 203, and orifices 409 to retain canister assembly 401 in a generally fixed position relative to flange mount 203, so that cable 309 can be detached therefrom. Note that openings 225 may be plugged when not in use to inhibit well gases from escaping therethrough.

Still referring to Figure 1, head assembly 501 comprises a packing gland
30 assembly 503, a head housing 505, a check valve 507, and a heater blanket 509

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(shown in phantom for clarity). Cable 309 extends through packing gland assembly 503 and into flange mount 203 when canister assembly 401 is in its upper position. When canister assembly 401 is lowered into well 109, cable 309 moves through packing gland assembly 503, head housing 505, base 209, flange mount 203, and well casing 107 into well 109. Note that the position of head housing 505 is adjustable with respect to base 209. Head housing 505 defines a check valve port 511 (shown in Figure 2) to which check valve 507 is attached. Check valve 507 allows gases to enter head housing 505 under certain conditions, *i.e.*, when canister assembly 401 is lowered into well 109 from its home position, but inhibits gases from flowing from head housing 505, as will be discussed in greater detail below. Heater blanket 509 heats head housing 505 to inhibit paraffins and other such waxy solids from depositing on interior surfaces of head housing 505. Alternatively, head housing 505 may include an integral heater for heating head housing 505.

Referring now to Figure 2 in the drawings, nose assembly 403 of canister assembly 401, head assembly 501, and the interaction between nose assembly 403 and head assembly 501 are illustrated in greater detail. In the illustrated embodiment, packing gland assembly 503 comprises a packing set 513 disposed in a packing gland housing 515. Packing gland housing 515 comprises a body 517 attached to a lower flange 519 and a cap 521 threadedly engaged with body 517. Lower flange 519 of packing gland housing 515 is attached to head housing 505. Packing set 513 is urged downward, toward lower flange 519, by a biasing element 523 disposed between packing set 513 and cap 521. In the illustrated embodiment, biasing element 523 comprises a spring.

Cap 521 defines a passageway 525, packing set 153 defines a passageway 527, and lower flange 519 defines a passageway 529. Cable 309 extends through passageways 525, 527, 529 and is attached to nose assembly 403 of canister assembly 401. Passageway 525 of cap 521 and passageway 529 of lower flange 519 are sized so that cable 309 is inhibited from contacting cap 521 and lower flange 519. Passageway 527 of packing set 513 is sized so that cable 309 is substantially sealed against packing set 513 but can slide through passageway 527. In this way, gases and liquids produced from well 109 are inhibited from exiting through

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passageway 527 to the atmosphere. Packing set 513 may be a single element or may comprise a plurality of layers. For example, in one embodiment, packing set 513 comprises layers 531, 533, 535, 537, 539, and 541. In one such embodiment, layers 531, 533 comprise a polytetrafluoroethylene-based polymer; layers 535, 537
5 comprise a silicone elastomer; and layers 539, 541 comprise a felt. In another embodiment, layers 535, 537 instead comprise a fluoroelastomer, such as Viton[®], manufactured by DuPont Performance Elastomers.

Still referring to Figure 2, nose assembly 403 of canister assembly 401 comprises a nose 415, at least two elastomeric seals 417, 418, and a pin 419. An
10 eye 321 is attached to a lower end 323 of cable 309. Nose 415 defines a passageway 421 and a slot 423. Eye 321 is received in slot 423, such that an opening defined by eye 321 is generally aligned with passageway 421. Pin 419 is received in passageway 421, through eye 321, to attach cable 309 to nose 415. Nose 415 further defines seal grooves 427, 429. Seals 417, 418 are captured in
15 grooves 427, 429, respectively. Head housing 505 defines a cavity 543 in which nose assembly 403 is received when canister assembly 401 is in its upper position. When nose assembly 403 is received in cavity 543, seals 417, 418 inhibit gas and liquid flow from well 109 between nose 415 and head housing 505. Note that, in the illustrated embodiment, passageway 421 extends into seal groove 427, so that fluids
20 are inhibited from flowing through passageway 421 by sealing element 417.

Coupling 405 of canister assembly 401 defines a fluid passageway 431 that is in fluid communication with a first fluid passageway 433. First fluid passageway 433 extends through a lower surface 435 of nose 415, generally axially into nose 415. A second fluid passageway 437 extends generally radially through nose 415,
25 terminating in recess 439 and intersecting first fluid passageway 433. Thus, as will be more fully described below, fluid from well 109 flows through fluid passageways 431, 433, 437 and into a fluid outlet port 545, defined by head housing 505, as indicated by arrow 805. A biasing element 547 is attached to head housing 505 within cavity 543 to cushion the arrival of nose assembly 403 into cavity 543 and to
30 urge canister assembly 401 downward into well 109, as will be more fully described below. Note that cable 309 extends through biasing element 547 to nose 415.

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Heater blanket 509 extends over at least a portion of head housing 505 and is powered by a source of electrical power (not shown) via electrical cable 549.

Turning now to Figure 3, pumping assembly 601 comprises a pump motor 603, a pump 605, a pumping inlet line 607, a solenoid valve 609, and a pumping outlet line 611. Pump motor 603, pump 605, and pumping outlet line 611 are also shown in Figure 1. When solenoid valve 609 is opened and pump motor 603 is activated, fluid is pumped from cavity 413 of canister 407 and from recovery reservoir 207 to fluid storage, as will be more fully described below. In one embodiment, pump 605 is a gear-driven, positive-displacement, mechanical evacuation pump.

Referring now to both Figure 1 and Figure 4, closed-loop control system 701 comprises a controller 703, a data display device 705, an operator input device 707, a variable frequency drive 709, a motor contactor set 711, a solenoid valve 713, a flow sensor 715, a canister position sensor 717, a canister depth sensor 719, a load sensor 721, and, in some embodiments, one or more network devices 723 and a water sensor 739. In one embodiment, controller 703 comprises a programmable logic controller. Data display device 705 provides a visual display of operating conditions and parameters for fluid lift system 101. Operator input device 707 allows a person to input values to controller 703; however, such values may be inputted to controller 703 by network device 723. Note that data display device 705 and operator input device 707 may comprise separate elements or may be combined into one element. It should be understood that data display device 705 and operator input device 707 may comprise graphical user interfaces that allow authorized personnel to interact with fluid lift system 101. For example, controller 703 may include a graphical user interface maintenance program that indicates graphically which components of fluid lift system 101 are functioning properly and which components are malfunctioning, and which allows authorized personnel to "step through" certain repair or maintenance procedures. In addition, data display device 705 and operator input device may be integral with each other, as a touch-screen, for example.

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Variable frequency drive 709 drives reel motor 303 and pump motor 603 through motor contactor set 711. In other words, motor contactor set 711 allows both motors 303, 603 to be driven by a single variable frequency drive 709, as controller 703 selects and closes separate contacts of motor contactor set 711 corresponding to which motor 303, 603 is to be driven. In the embodiment illustrated in Figure 1, controller 703, variable frequency drive 709, and motor contactor set 711 are disposed in enclosure 725. Data display device 705 and operator input device 707 extend from enclosure 725 for access by personnel. Solenoid valve 713 is disposed in fluid communication with pump 605 (best shown in Figure 3) for selectively allowing the flow of fluid from cavity 413 of canister 407. Flow sensor 715, also in fluid communication with pump 605, provides an indication to controller 703 that fluid is flowing from cavity 413 of canister 407. Water sensor 739, if present, is also in fluid communication with pump 605 and provides an indication of water in the fluid being lifted from well 109.

Canister position sensor 717 indicates when canister assembly 401 is in its "home" position, *i.e.*, when recess 439 of nose 415 is aligned with fluid outlet port 545 (see Figure 2). Canister depth sensor 719 provides an indication of the depth of canister assembly 401 within well 109 to controller 703. In various embodiments, canister position sensor 717 and/or canister depth sensor 719 comprise proximity sensors. In embodiments wherein canister position sensor 717 is a proximity sensor, canister position sensor 717 senses the presence of canister assembly 401. In embodiments wherein canister depth sensor 719 comprises a proximity sensor, canister depth sensor 719 senses a feature of sheave 311 (shown in Figure 1), such as a slot or opening in sheave 311, as sheave 311 rotates about load-indicating shaft 313, providing a pulse to controller 703. Pulses are counted by controller 703, such that each pulse corresponds to a certain rotation of sheave 311.

Still referring to Figures 1 and 4, load sensor 721 is incorporated into load indicating shaft 313. Load sensor 721 provides controller 703 an indication of the load on cable 309. In one embodiment, load sensor 721 comprises a plurality of strain gauges, configured as a Wheatstone bridge, disposed within load indicating shaft 313. In one particular embodiment shown in Figure 5, load-indicating shaft 313

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comprises a shaft 727 defining a cavity 729 and a groove 731. Load sensor 721 is disposed within cavity 729 adjacent groove 731, so that deflections resulting from the loading of shaft 727 by cable 309 are exaggerated proximate load sensor 721, due to the decreased cross-sectional area of shaft 727 at groove 731. Preferably, load sensor 721 comprises a full-bridge strain gauge configuration, as shown in Figure 6, as such a configuration is sensitive to bending strain in shaft 727, while rejecting axial strain in shaft 727. Such a configuration also is self-compensating for electrical resistance changes in electrical leads extending from the strain gauges and for temperature variations. Strain gauges R_1 , R_2 , R_3 , R_4 , forming a strain gauge assembly 733, are bonded to a foil 735. Foil 735 is rolled such that strain gauge R_4 is above strain gauge R_3 and such that strain gauge R_1 is above strain gauge R_2 . Foil 735 is bonded to the surface of cavity 729 proximate groove 731. Strain gauge assembly 733 is excited with a voltage applied to points between strain gauges R_1 and R_4 , and between strain gauges R_2 and R_3 . A voltage is then measured between points between R_1 and R_2 , and between R_3 , and R_4 . The measured voltage is conditioned by signal conditioner 737, which is electrically coupled between load sensor 721 and controller 703. Note that signal conditioner 737 may be incorporated into load sensor 721. It should also be noted that other strain gauge configurations, such as quarter-bridge and half-bridge configurations, are within the scope of the present invention. Other configurations of load sensor 721 are also within the scope of the present invention.

Network device 723 may comprise a computer, a network interface card, a modem, a printer, a data recording device, or the like. Network device 723 may be located proximate controller 703 or may be remote from controller 703. For example, network device 723 may be a remote computer linked to controller 703 via a wired, a wireless, or a radio network or connection. Moreover, a plurality of network devices 723 may be linked to controller 703, as will be discussed in greater detail below, depending upon the application for which network device 723 is implemented.

Generally, controller 703 is programmed to operate reel motor 303, pump motor 603, and solenoid valve 713 to lift fluid from well 109, based upon the amount

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of fluid to be lifted from well 109 and outputs from flow sensor 715, canister position sensor 717, canister depth sensor 719, and load sensor 721. In some embodiments, controller 703 may operate based upon instructions from network device 723, as will be discussed in greater detail below. Controller 703 may be programmed using
5 operator input device 707, via network device 723, or via a direct communication link, such as a serial communication link. Note that fluid lift system 101 is operated, as described below, by controller 703.

Referring now to Figures 7A-7D in the drawings, the operation of fluid lift system 101 will now be described in more detail. At the beginning of a fluid lifting
10 cycle, canister assembly 401 is in its home position, such that nose assembly 403 is received in cavity 543 of head housing 505, as shown in Figure 2. Controller 703 closes motor contact set 711 corresponding to reel motor 303 and commands variable frequency drive 709 to operate reel motor 303, such that reel 307 is rotated slowly to slowly pay out cable 309. Biasing element 547 urges canister assembly
15 401 downward into well 109. Check valve 507 allows ambient air to enter cavity 543 of head housing 505, thus venting any vacuum formed as canister assembly 401 moves downward, while inhibiting gases within well 109 from escaping to the atmosphere. Controller 703 begins calculating the length of cable 309 being paid out by counting pulses from canister depth sensor 719. Once canister assembly 401 is
20 moved away from its home position by a predetermined distance X, as shown in Figure 7A, controller instructs variable frequency drive 709 to operate reel motor 303, such that reel 307 is rotated quickly to quickly pay out cable 309. Controller continues to calculate the length of cable being paid out by counting pulses from canister depth sensor 719.

As shown in Figure 7B, once canister assembly 401 is within a predetermined
25 distance Y from a top 801 of a fluid pad 803 within well 109, controller commands variable frequency drive 709 to operate reel motor 303, such that reel 307 is again slowly rotated to slowly pay out cable 309. Note that the location of top 801 of fluid pad 803 may have been inputted to controller 703 by an operator or via network
30 device 723. Alternatively, top 801 of fluid pad 803 may be known to controller 703

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from a previous lifting cycle. The location of top 801 of fluid pad 803 is determined and/or updated by controller 703 during each lifting cycle of fluid lift system 101.

Controller 703 calculates a weight value corresponding to the load applied to load-indicating shaft 313 by analyzing the signal transmitted by load sensor 721. This load is due to the weight of substantially empty canister assembly 401 and cable 309 attached thereto. Thus, the calculated value is a beginning or "zero" weight value. Controller 703 recalculates the weight value as canister assembly 401 is further lowered into well, based upon the length of cable 309 payed out and the known weight of cable 309 per unit length. As cable 309 is payed out, controller 703 monitors the signal from load sensor 721.

As shown in Figure 7C, when canister 407 contacts and enters fluid pad 803 within well 109, canister assembly 401 becomes partially buoyant, resulting in a reduced weight value signal being generated by load sensor 721. Controller 703 records the payed-out length of cable 309 plus the length of canister assembly 401 as the distance from the canister assembly's 401 home position to a new top 801 of fluid pad 803 within well 109, which can be used in subsequent lifting cycles and to determine if the level of fluid pad 803 is changing. Note that, if top 801 of fluid pad 803 is below a predetermined depth within well 109, controller 703 halts or slows the rate of the fluid lifting process, thereby preventing any premature or undesirable depletion of the fluids in the well. Controller 703 may raise canister assembly 401 to its home position or leave canister assembly 401 at another position within well 109. Controller 703 records the depth of top 801 of fluid pad 803 and, in some embodiments, transmits the depth and an alarm to network device 723.

Reel 307 continues to pay out cable 309 until a predetermined additional length of cable 309 is payed out, lowering canister assembly 401 into fluid pad 803 by a predetermined distance Z, as shown in Figure 7D. In one embodiment, canister assembly 401 is lowered to within a predetermined range 804 of predetermined distance Z. Lowering canister assembly 401 into fluid pad 803 by such a distance provides sufficient head pressure to displace the air within canister 407 and to fill canister 407 through orifices 409.

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Once canister assembly 401 is submerged within fluid pad 803 at the desired position or within the desired range of positions, as described above and shown in Figure 7D, controller 703 instructs variable frequency drive 709 to stop reel motor 303, thus halting the progression of canister assembly 401 downward. Controller
5 703 starts a dwell timer, so that canister assembly 401 will remain submerged within fluid pad 803 for a sufficient amount of time to fill cavity 413 of canister 407 through orifices 409. The time required to fill cavity 413 is dependent upon the volume of cavity 413 and other parameters, such as the viscosity of the fluids flowing into cavity 413. Thus, the dwell time is implementation specific.

10 After the dwell timer has timed out, controller 703 instructs variable frequency drive 709 to operate reel motor 303 to first slowly, then quickly rotate reel 307, which first slowly, then quickly winds cable 309 onto reel 307. Note that as canister assembly 401 moves upward through well 109, canister assembly 401 urges gases within well 109 above canister assembly 401 through gas outlet port 115, so that the
15 gases can be collected, rather than merely vented to the atmosphere. Cable 309 is wound onto reel 307 until canister assembly 401 is within a distance X of its home position, as illustrated in Figure 7A. Controller 703 then instructs variable frequency drive 709 to operate reel motor 303 to slowly rotate reel 307, thus slowly winding cable 309 onto reel 307. Controller 703 monitors canister position sensor 717 for an
20 indication that canister assembly 401 is in its home position.

In the home position, nose 415 of canister assembly 401 is received in cavity 543 of head housing 505, such that recess 439 of nose 415 is adjacent fluid outlet port 545 of head housing 505. When canister assembly 401 is in its home position, controller 703 commands reel motor 303 to stop. Controller 703 then commands
25 solenoid valve 713 to open, opens motor contact set 711 corresponding to reel motor 303, closes motor contact set 711 corresponding to pump motor 603, and commands variable frequency drive 709 to actuate pump motor 603. The fluid is vacuum pumped by pump motor 603 from within cavity 413 of canister 407, through fluid passageway 431 of coupling 405, first fluid passageway 433 of nose 415,
30 second fluid passageway 437 of nose 415, and into fluid outlet port 545 of head housing 505, as indicated by arrow 805 in Figure 2. Fluid flows through pumping

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inlet line 607, past solenoid valve 609, and through flow sensor 715, pump 605, and pumping outlet line 611 (see Figure 3) to a fluid storage facility (not shown). Flow sensor 715 provides an indication to controller 703 that fluid is flowing therethrough and provides an indication to controller 703 that fluid flow has ceased when cavity
5 413 of canister 407 has been substantially emptied. When flow sensor 715 indicates no further substantial flow, controller 703 commands variable frequency drive 709 to stop pump motor 603, opens motor contact set 711 corresponding to pump motor 603, and closes solenoid valve 609. The lifting cycle can now be repeated, if desired. Note that, when fluid is pumped from cavity 413 of canister 407, fluid, if
10 present, is also pumped from recovery reservoir 207.

In one embodiment, controller 703 records the number of lifting cycles performed by fluid lift system 101 during a specific time period and calculates the amount of fluid lifted by fluid lift system 101. Controller 703 then communicates the amount of fluid lifted and the time period to network device 723. Controller 703 may
15 also use the amount of fluid lifted by fluid lift system 101 during a particular time period to determine whether to continue lifting fluid from well 109 or to determine the number of lifting cycles to implement during a particular time frame.

If well 109 is an oil well, it is likely that fluid pad 803 comprises an oil portion 807 upwardly displaced by a water portion 809. It is preferable to fill canister 407
20 with oil rather than water. Since canister assembly 401 is more buoyant in water than in oil, signals from load sensor 721 can be monitored by controller 703 as canister assembly 401 is being lowered into fluid pad 803 to determine if canister assembly 401 has entered water portion 809. Moreover, control system 701 may include a water sensor 739 (shown in Figures 3 and 4) disposed in fluid
25 communication with pump 605. The lifting process can be halted, an alarm can be sounded, a message can be sent to network device 723, and/or canister assembly 401 returned to its home position if water portion 809 is entered. Alternatively, controller 703 can instruct variable frequency drive 709 to rotate reel motor 303 to rotate reel 307 such that cable is wound onto reel 307 for a specified distance, thus
30 raising canister assembly 401 fully into oil portion 807. Canister assembly 401 can then be filled and returned to its home position.

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As discussed above, controller 703 may be in data communication with one or more network devices 723, for example, via hard-wired data connections and/or wireless data connections. Network device 723 may take on various forms within the scope of the present invention depending upon the particular implementation of fluid lift system 101. For example, network device 723 may comprise a remote computer associated with an owner of well 109 for reporting various data, such as the amount of fluid lifted from well 109. Network device 723 may comprise a remote computer associated with an operator of well 109 for receiving and transmitting various data, for example, the amount of fluid lifted from well 109 and/or the maintenance history of the fluid lift system 101. Moreover, network device 723 may comprise a remote computer associated with a governmental agency responsible for regulating the operation of well 109 for reporting various data, for example, the amount of fluid lifted from well 109 and/or the amount of gas captured from the well. In addition, network device 723 may be a computerized data transfer system for receiving and transmitting maintenance related data, programs, and functions. In such embodiments, the remote maintenance computer may be used to diagnose problems existing in fluid lift system 101 or input maintenance related values to controller 703. Controller 703 may send data to network device 723 or network device 723 may poll or request data from controller 703. In one embodiment, network device 723 is a supervisory control and data acquisition (SCADA) system that performs a supervisory role over fluid lift system 101. In one embodiment, at least one of the data connections is accomplished via the internet.

While certain embodiments of fluid lift system 101 are powered using conventional, electrical power provided by an electrical utility, the present invention is not so limited. Rather, components of fluid lift system 101 requiring electrical power may be powered using other sources of electricity, such as from an engine-powered generator or a solar energy system. Specifically, in one embodiment, fluid lift system 101 includes a solar energy system 901, shown in Figure 8. In the illustrated embodiment, solar energy system 901 comprises a solar energy collection system 903, such as a solar array; a rechargeable electrical power source 905, such as one or more batteries; and an inverter 907, for converting the solar-generated DC

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electrical power into AC electrical power. In various embodiments, some or all of the electrically-powered components of fluid lift system 101 are adapted to be powered with electricity provided by solar energy system 901.

5 In normal operation, packing set 513, pin 419, and elastomeric seals 417, 418 experience wear and are replaced periodically as a preventative maintenance measure. The scope of the present invention encompasses providing packing set 513, pin 419, and elastomeric seals 417, 418 as a kit for replacement in fluid lift system 101. Moreover, the scope of the present invention encompasses a method of replacing a worn packing set 513, pin 419, and/or worn elastomeric seals 417, 418
10 in fluid lift system 101 with a new packing set 513, a new pin 419, and/or new elastomeric seals 417, 418. In one embodiment, a method of replacing packing set 513, pin 419, and elastomeric seals 417, 418 includes restraining canister assembly 401 so that canister assembly 401 cannot fall down well 109. Head assembly 501 is detached from base 209 of frame assembly 201 and cable 309 is detached from
15 canister assembly 401 by removing worn pin 419. Worn elastomeric seals 417, 418 are removed and replaced with new elastomeric seals 417, 418. Cable 309 is removed from passageway 527 of packing set 513. Cap 521 of packing gland assembly 503 is removed to reveal packing set 513. Biasing element 523 is removed from packing gland housing 515, as is worn packing set 513. New packing
20 set 513 is placed in packing gland housing 515 and biasing element 523 is replaced. Cap 521 is replaced on packing gland housing 515 and cable 309 is threaded through passageway 527 of packing set 513. Cable 309 is reattached to canister assembly 401 with new pin 419 and head assembly 501 is reattached to base 209. Canister assembly 401 is, then, freed for use in lifting fluid from well 109. Moreover,
25 the scope of the present invention encompasses providing replacement parts for fluid lift system 101, including providing each of the components of fluid lift system 101 separately or in groups, kits, or assemblies, such as the assemblies 103, 201, 301, 401, 501, 601, 701 disclosed herein or subsets of such assemblies. Furthermore, the scope of the present invention encompasses a method of replacing
30 any of the components of fluid lift system 101.

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Figure 9 depicts an alternative, illustrative, embodiment of a portion of a fluid lift system according to the present invention. In particular, Figure 9 depicts an elastomeric member 1001 disposed in a bore 1003 defined by a head housing 1005. In one embodiment, elastomeric member 1001 comprises a fluoroelastomer, such as Viton[®]. A canister 1007, which is used to lift fluids from a well, seals against elastomeric member 1001 at a first interface, generally at 1009, and at a second interface, generally at 1011. Elastomeric member 1001 and head housing 1005 further define a port 1013, through which lifted fluids are vacuum evacuated from a canister 1009. In this embodiment, no biasing element, such as biasing element 547 of Figure 2, is needed to cushion the arrival of canister 1007 into bore 1003 and to urge canister 1007 downward into the well. Other aspects of this particular embodiment generally correspond to the aspects of the other embodiments disclosed above.

Figure 10 depicts an alternative, illustrative, preferred embodiment of a portion of a fluid lift system according to the present invention. In particular, Figure 10 depicts a base 1101, a tank 1103, a pump 1105, a pump motor 1107, a first three-way valve 1109, a second three-way valve 1111, and a head assembly 1113. In this particular embodiment, an inlet side of pump 1105 is in fluid communication with head assembly 1113 and with tank 1103 through first three-way valve 1109. Moreover, pump 1105 is in fluid communication with tank 1103 and with a fluid recovery line 1115 via second three-way valve 1111. Tank 1103 is disposed below base 1101. When fluids are to be vacuum evacuated from a canister parked in head assembly 1113, three-way valves 1109, 1111 are positioned to a first position, such that pump 1105 vacuum evacuates the fluids from the canister, through housing assembly 1113, through first three-way valve 1109, and into pump 1105. The fluids are then urged through second three-way valve 1111 and into tank 1103. When the fluids are to be moved from tank 1103 into the fluid recovery line, three-way valves 1109, 1111 are positioned to a second position, such that pump 1105 urges the fluids from tank 1103, through pump 1105, and into fluid recovery line 1115. In one embodiment, at least one of three-way valves 1109, 1111 is a three-way ball valve.

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In any case, three-way valves 1109, 1111 are controlled by a control system, such as control system 701 of Figure 1.

Preferably, fluids within tank 1103 is recirculated by pump 1107 prior to vacuum-evacuating fluids from the canister and prior to urging fluids from tank 1103 into the fluid recovery line. Recirculation is accomplished by positioning three-way valves 1109 and 1111 so that fluids are drawn from tank 1103, through valve 1109, through pump 1105, through valve 1111, and into tank 1103. Recirculating fluids within tank 1103 aids in keeping pump 1105 primed.

In one embodiment, a tank level sensor, such as a float switch 1117, is disposed in tank 1103 to sense a desired level of fluid in tank 1103. In the illustrated embodiment, float switch 1117 is coupled with a control system, such as control system 701 of Figure 1. In one embodiment, the tank level sensor determines when one-half barrel of fluid is present in tank 1103. The use of a tank level sensor allows the control system to determine the volume of fluids delivered to recovery line 1115, which can be compared to the volume of fluids received at a remote storage tank to indicate if leaks are present in recovery line 1115. Moreover, use of such a tank level sensor allows the control system to determine if the fluid lift system is properly lifting fluid from a well. For example, if the tank level sensor has not indicated that the predetermined level has been reached after a set number of lifting cycles, the fluid lifting system can be halted and an error message sent, for example via network device 723 of Figure 4, to alert personnel of the problem.

Figure 11 depicts an alternative, illustrative, preferred embodiment of a portion of a fluid lift system according to the present invention. In particular, Figure 11 depicts an elastomeric member 1201 disposed in a bore 1203 defined by a head housing 1205. In one embodiment, elastomeric member 1201 comprises a fluoroelastomer, such as Viton[®], manufactured by DuPont Performance Elastomers. A canister 1207, which is used to lift fluids from a well, seals against elastomeric member 1201 at a first interface, generally at 1209, and at a second interface, generally at 1211. In the illustrated embodiment, canister 1207 and elastomeric member 1201 are radiused at first interface 1209 and at second interface 1211,

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which provides improved sealing at interfaces 1209 and 1211 especially when canister 1207 is misaligned within bore 1203. Elastomeric member 1201 and head housing 1205 further define a port 1213, through which lifted fluids are vacuum evacuated from a canister 1209. In this embodiment, no biasing element, such as
5 biasing element 547 of Figure 2, is needed to cushion the arrival of canister 1207 into bore 1203 and to urge canister 1207 downward into the well. Other aspects of this particular embodiment generally correspond to the aspects of the other embodiments disclosed above.

Figure 12 depicts an illustrative embodiment of a packing set 1301, which is
10 alternative to packing set 513. Packing set 1301 comprises layers 1303, 1305, 1307, 1309, 1311, 1313, and 1315. In one particular configuration of the illustrative embodiment, layers 1303 and 1305 comprise a polytetrafluoroethylene-based polymer; layers 1307 and 1309 comprise a silicone elastomer; layers 1311 and 1313 comprise a felt; and layer 1315 comprises leather. In an alternative configuration of
15 the illustrative embodiment, layers 1303 and 1305 comprise a polytetrafluoroethylene-based polymer; layers 1307 and 1309 comprise a fluoroelastomer, such as Viton[®]; layers 1311 and 1313 comprise a felt; and layer 1315 comprises leather. Such configurations provide improved sealing over other configurations when lifting certain fluids.

Figure 13 depicts an illustrative embodiment of a load indicating shaft 1401
20 according to the present invention, which is alternative embodiment to load indicating shaft 313 of Figure 5. In the illustrated embodiment, a signal conditioner 1403, corresponding in function to signal conditioner 737 of Figure 5, is incorporated within shaft 727. Other aspects of load indicating shaft 1401 correspond to load indicating
25 shaft 313.

Figure 14 depicts a stylized view of a portion of an alternative embodiment of a fluid lift system 1501 according to the present invention. While some components of system 1501 have been removed in Figure 14 to improve clarity, the illustrated embodiment includes the components of fluid lift system 101 with the addition of a
30 traveling sheave 1503. As discussed herein with regard to Figure 1, cable 309 is

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attached at a first end to reel 307 and is wound thereon, such that cable 309 can be
payed out from and retrieved onto reel 307. Cable 309 extends around sheave 311
and, in the illustrated embodiment, extends around traveling sheave 1501. Cable
309 extends through packing gland assembly 503 and is attached at a second end to
5 canister assembly 401 (shown in Figure 1).

Referring now to Figure 15, traveling sheave 1501 aids in properly winding
cable 309 onto reel 307. As shown in Figure 15, traveling sheave 1501 is rotatably
mounted to a shaft 1503, which is attached to supports 1505 and 1507. Traveling
sheave 1501 is free to rotate about and along shaft 1503. Thus, as cable 309 is
10 payed out from and retrieved onto reel 307, traveling sheave 1501 rotates about
shaft 1503 and traverses along shaft 1503, as indicated by an arrow 1509. Note that
traveling sheave 1501 is shown in phantom in a second of many positions along
shaft 1503.

Figure 16 depicts a preferred coupling between cable 309 and canister 407.
15 In the illustrated embodiment, a swivel 1601 mechanically couples cable 309 and
canister 407. Coupling comprises an upper portion 1603 that is free to rotate about
an axis 1605 with respect to a lower portion 1607 via a bearing 1609. Cable 309 is
coupled with swivel 1601 via cable sleeve 1611. In the illustrated embodiment, lower
portion 1607 is threadedly engaged with canister 407 or, in some embodiments, a
20 fitting attached to canister 407. Preferably, lower portion 1607 is inhibited from
withdrawing from canister 407 by a set screw 1613 or the like. Coupling cable 309
with canister 407 via a swivel, such as swivel 1601, inhibits cable 309 from becoming
twisted as cable 309 is payed out from and retrieved onto spool 307 (shown in
Figures 1 and 14).

25 It should be noted that preferably canister embodiments of the present
invention are lightweight in nature. It should also be noted that the present invention
may be utilized for other operations on a well. For example, a camera may be
attached or otherwise coupled with a canister of the present invention, so that an
interior of a well may be inspected. In one case, the camera is a wireless web
30 camera. Moreover, the present invention may be used to chemically treat a well. In

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such an embodiment, one or more chemicals are introduced into a head housing through a port, such as port 545 or 913, and into a canister. The canister is then lowered into the fluid pool and the fluid pool is agitated by repeatedly raising and lowering the canister in the fluid pool to release the chemicals into the fluid pool. It should also be noted that a canister may be cleaned by introducing water through a head housing port, such as port 545 or 913 and into canister. A sufficient volume of water is introduced to flush undesirable matter from the canister and into the well. Preferably, the water is sufficiently heated so that paraffins are flushed from the canister.

It should be noted that the scope of the present invention encompasses accumulating data, such as volume of lifted fluid per unit time, well fluid level, well level at which fluid is lifted, and the like from a plurality of fluid lift systems. For example, such data may be used in geologic studies of the area in which the plurality of fluid lift systems is located. A plurality of fluid lift systems according to the present invention may be operably associated with a corresponding plurality of wells, such that the plurality of wells is a subset of a plurality of wells in a field. In one embodiment, the plurality of fluid lift systems is selectively located on wells within the field of wells. The scope of the present invention encompasses using the plurality of fluid lift systems to gather data which is used to determine fluid reserves in the larger plurality of wells in the field. One or more of the plurality of lift systems may include logging equipment operably associated with the canisters or other elements of the fluid lift systems to log data of interest about the fluid within the wells. It should be noted that the fluid lift systems may be used to produce fluid on an ongoing basis from the wells with which the fluid lift systems are operably associated or may be used on a temporary basis to gather data about the fluid within the wells.

The present invention provides significant advantages, including: (1) capturing and collecting gases from the wells from which fluid is being lifted, thereby improving cost effectiveness and avoiding ecological damage; (2) retrieving fluids from the wells without hazardous, potentially explosive, methods; (3) containing the fluids being lifted from wells, thereby avoiding ecological damage; (4) managing the production of fluid from the wells, thereby preventing the wells from being

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prematurely or undesirably depleted; (5) eliminating the need for high-tolerance components; (6) providing a low-maintenance fluid lift system that requires little adjustment for use; (7) providing a fluid lift system that includes a closed-loop, self-learning programmable controller; (8) providing a fluid lift system that retrieves
5 substantially only oil from oil wells, rather than fluids containing a substantial amount of water; (9) providing a fluid lift system that can be fixedly, but releasably, mounted to a well casing; (10) providing a fluid lift system that can automatically report amounts of fluid produced, and other operational data, to well owners, well operators, maintenance personnel, and regulatory agencies; (11) providing a fluid lift
10 system that can be remotely accessed to determine its operational status and condition; and (12) providing a fluid lift system that can be supervised using a remote computer system and/or network.

The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners
15 apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the invention. Accordingly,
20 the protection sought herein is as set forth in the claims below. It is apparent that an invention with significant advantages has been described and illustrated. Although the present invention is shown in a limited number of forms, it is not limited to just these forms, but is amenable to various changes and modifications without departing from the spirit thereof.

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Claims

1. A fluid lift system, comprising:

a canister defining a cavity for lifting fluid and an orifice at an upper portion of the canister extending to the cavity;

5 a reel;

a cable operably associated with the reel and the canister;

a motor operatively associated with the reel, the motor operable to raise and lower the canister;

10 a head housing defining a bore in which the upper portion of the canister is sealingly received, the head housing defining a port extending into the cavity;

a pump in fluid communication with the head housing, the pump operable to vacuum lifted fluid from the cavity of the canister through the orifice and the port; and

a control system for operating the motor and the pump.

15 2. The fluid lift system, according to claim 1, further comprising:

a load-indicating shaft mechanically linking the motor and the reel and operatively associated with the control system.

20 3. The fluid lift system, according to claim 2, wherein the control system is operable to determine contact between the canister and a top of a fluid pad based at least upon a signal from the load-indicating shaft.

25 4. The fluid lift system, according to claim 2, wherein the control system is operable to place the canister a predefined distance below the top of the fluid pad based at least upon a signal from the load-indicating shaft.

5. The fluid lift system, according to claim 2, wherein the control system is operable to determine if the canister enters a water portion based at least upon a signal from the load-indicating shaft.

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6. The fluid lift system, according to claim 5, wherein the control system is operable to move the canister from the water portion into the fluid pad.

7. The fluid lift system, according to claim 1, further comprising:
5 a storage tank in fluid communication with the pump for temporarily storing lifted fluid.

8. The fluid lift system, according to claim 7, further comprising:
a level sensor operatively associated with the tank and the control system for
10 sensing a level of fluid in the tank.

9. The fluid lift system, according to claim 8, wherein the control system is operable to pump the fluid from the tank based at least upon a signal from the level sensor.

15 10. The fluid lift system, according to claim 7, further comprising:
a first three-way valve in fluid communication with the head housing, the pump, and the tank; and
a second three-way valve in fluid communication with the pump and the tank,
20 the second three-way valve having a recovery line outlet port.

11. The fluid lift system, according to claim 1, further comprising:
a traveling sheave operably associated with the cable.

25 12. The fluid lift system, according to claim 1, further comprising:
an elastomeric member disposed in the bore of the head housing for sealingly receiving the upper portion of the canister.

13. The fluid lift system, according to claim 12, wherein the elastomeric
30 member and the upper portion of the canister define radiused sealing surfaces, such that the radiused sealing surface of the canister mates with the radiused sealing surface of the elastomeric member.

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14. The fluid lift system, according to claim 1, further comprising:
a swivel attached to the cable and operably associated with the canister.

5 15. A method of lifting fluid, comprising the steps of:
lowering a canister;
detecting a depth at which contact is made between the canister and a top of
a fluid pad;
lowering the canister to a predetermined depth below the top of the fluid pad;
10 waiting for the canister to at least partially fill with fluid;
raising the canister; and
vacuuming the fluid from the canister.

15 16. The method, according to claim 15, wherein the step of detecting
contact between the canister and the top of the fluid pad is accomplished by sensing
a change in a weight of the canister.

17. The method, according to claim 15, further comprising the step of:
detecting whether the canister has entered a second fluid pad having a
20 density different from the fluid pad.

18. The method, according to claim 17, wherein the step of detecting
whether the canister has entered the second fluid pad is accomplished by sensing a
change in a weight of the canister.

25 19. The method, according to claim 15, further comprising the step of:
determining the predetermined depth based at least upon the depth at which
contact is made between the canister and the fluid pad.

30 20. The method, according to claim 15, further comprising the step of:
collecting gases expelled from a well in which the fluid is disposed.

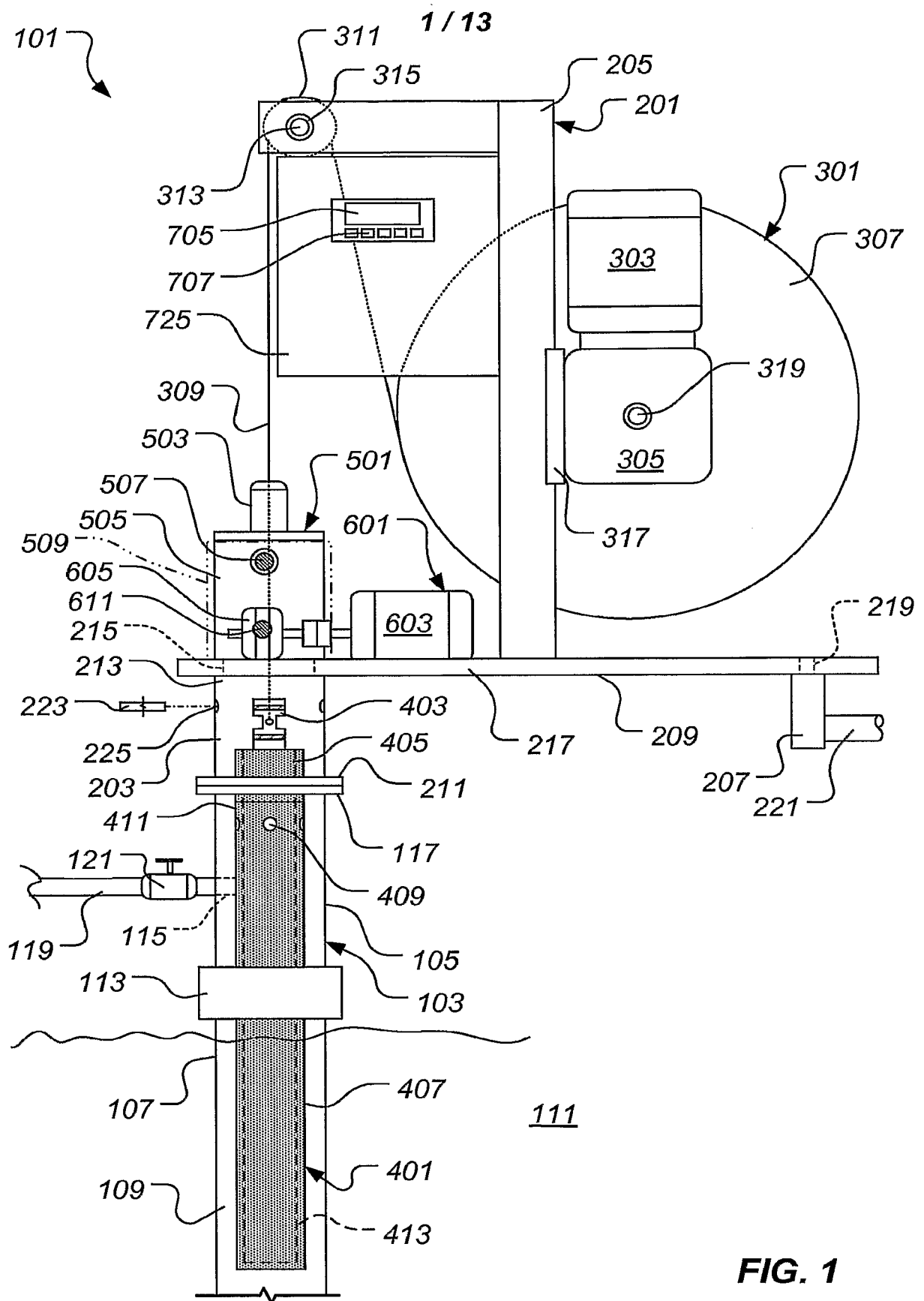


FIG. 1

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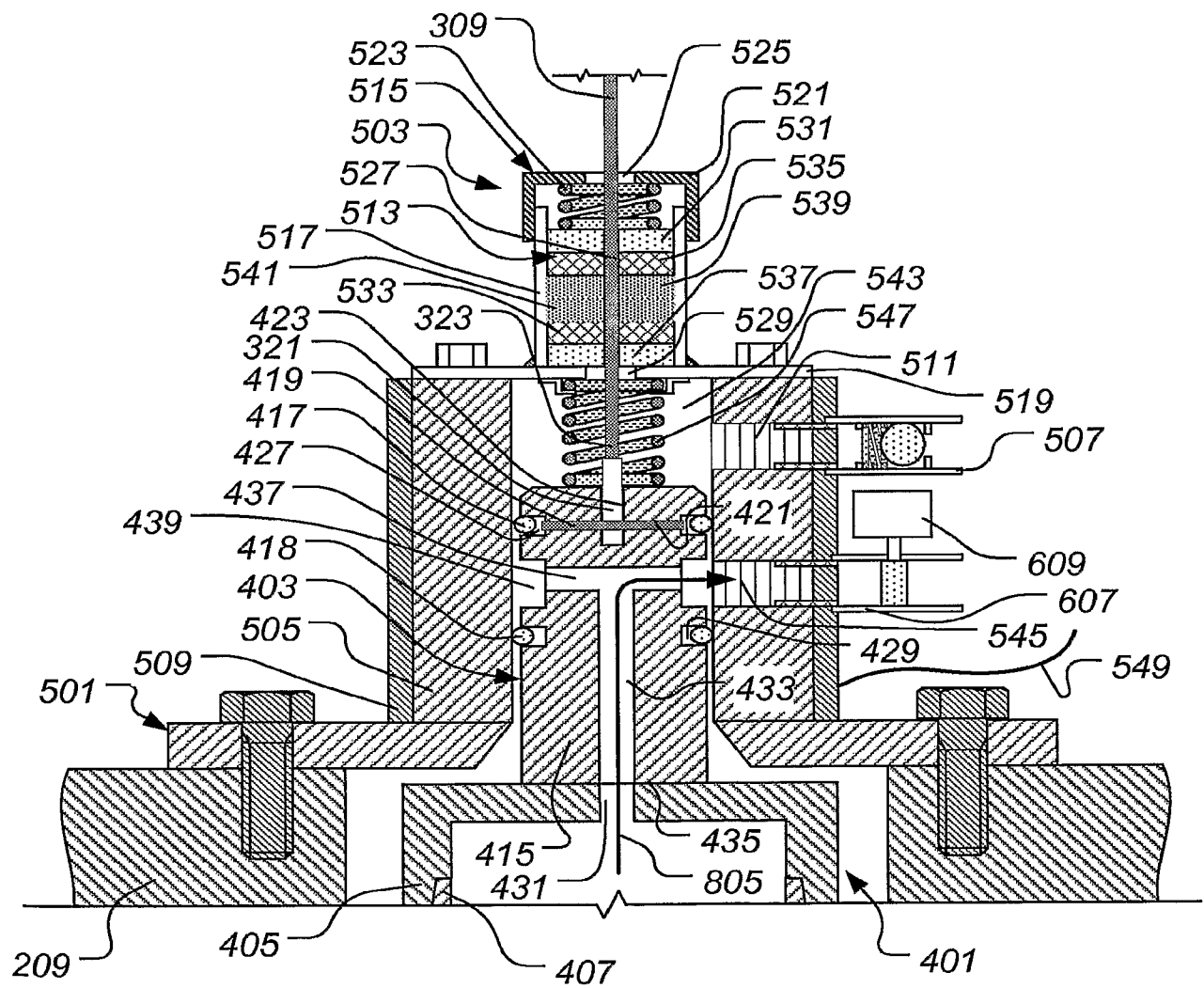


FIG. 2

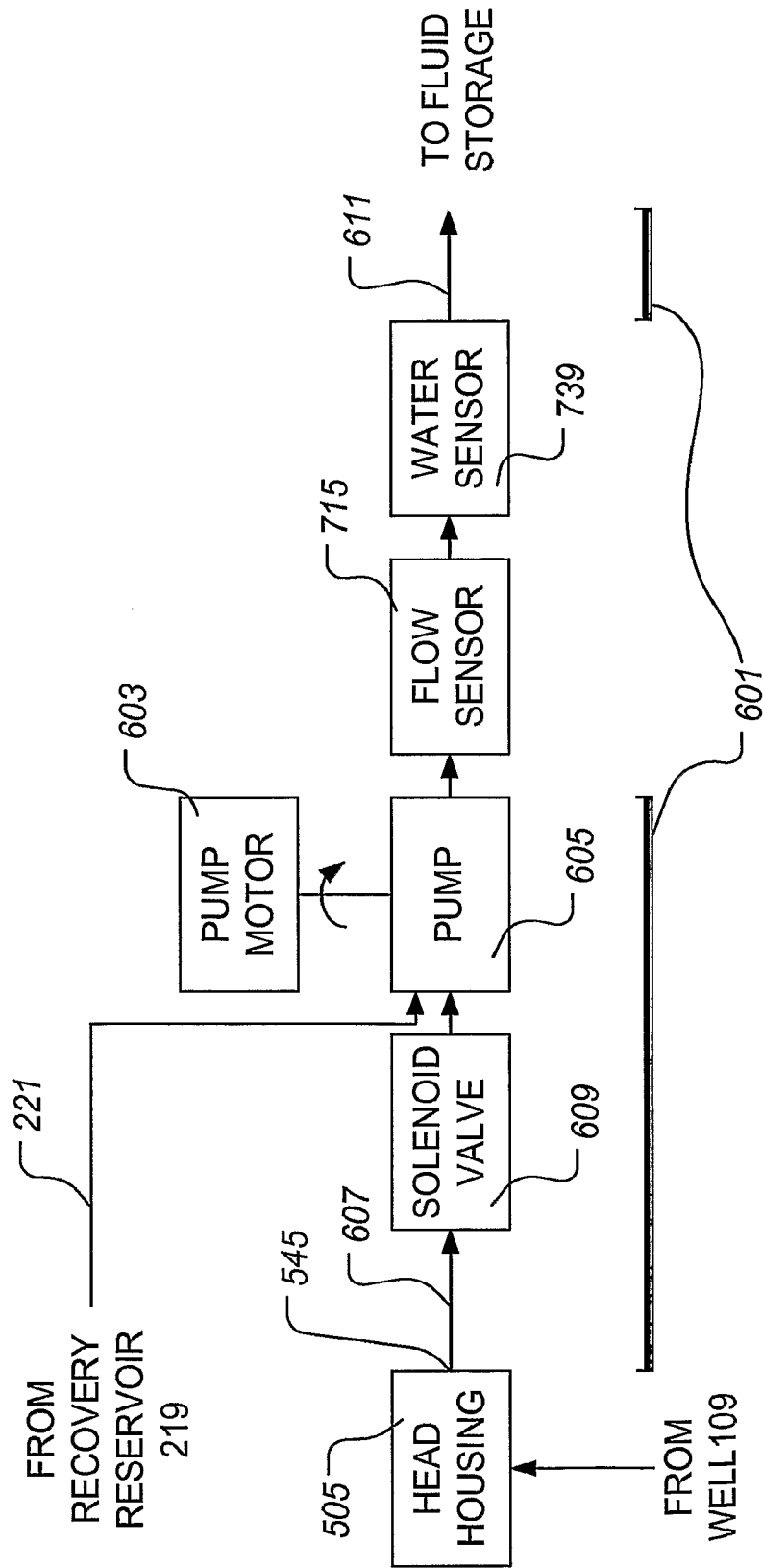
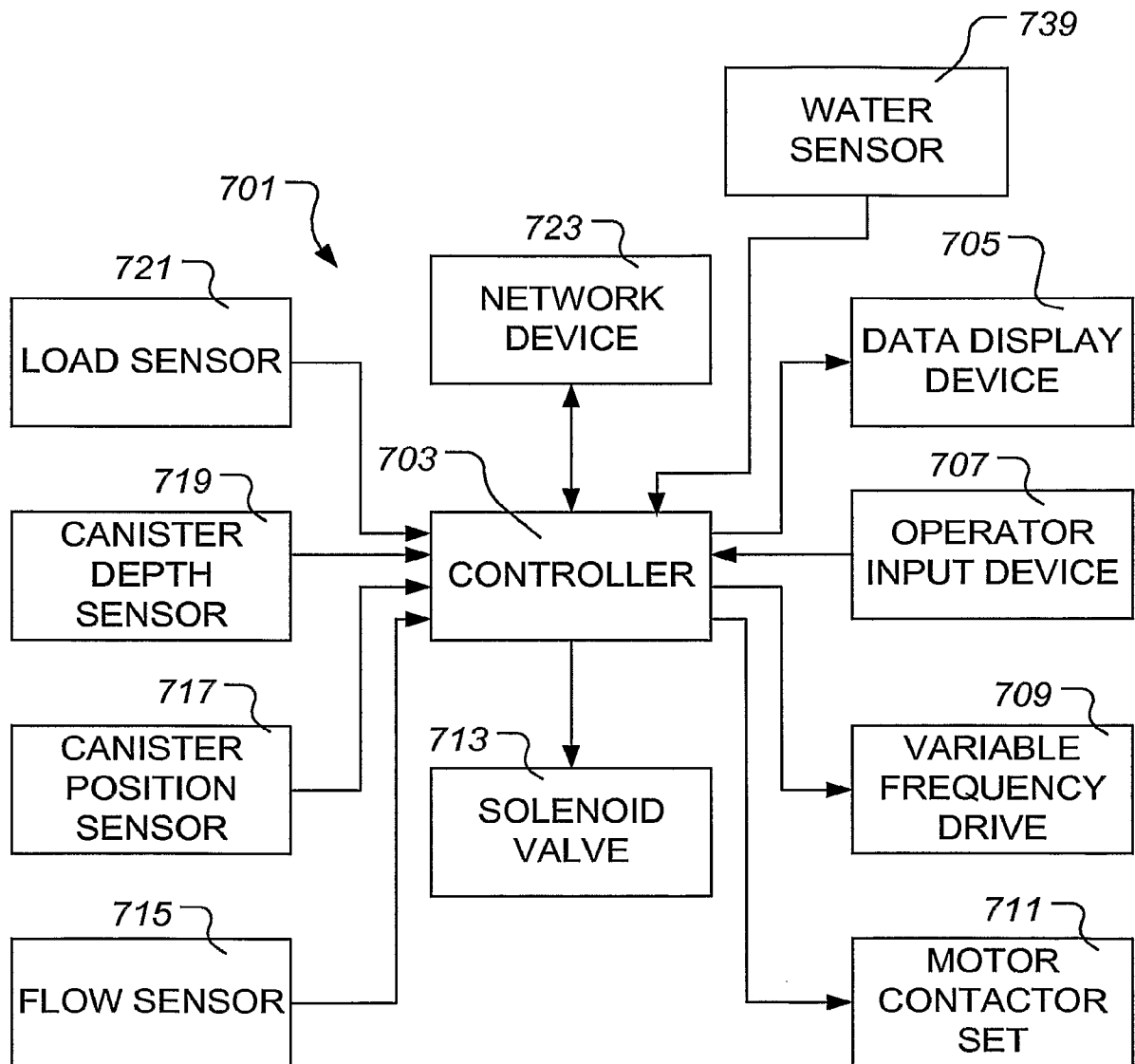


FIG. 3

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**FIG. 4**

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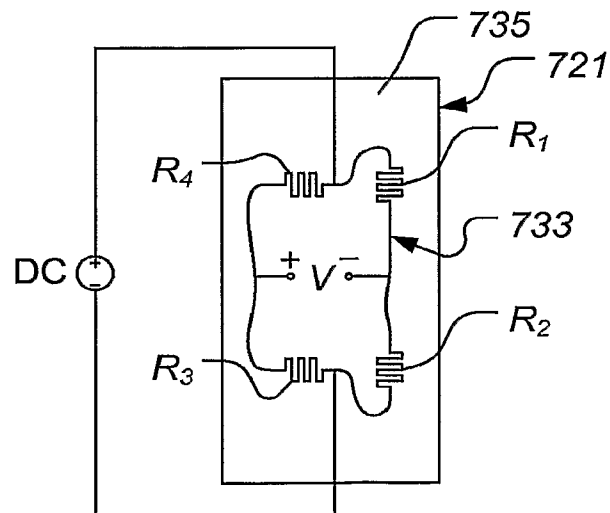
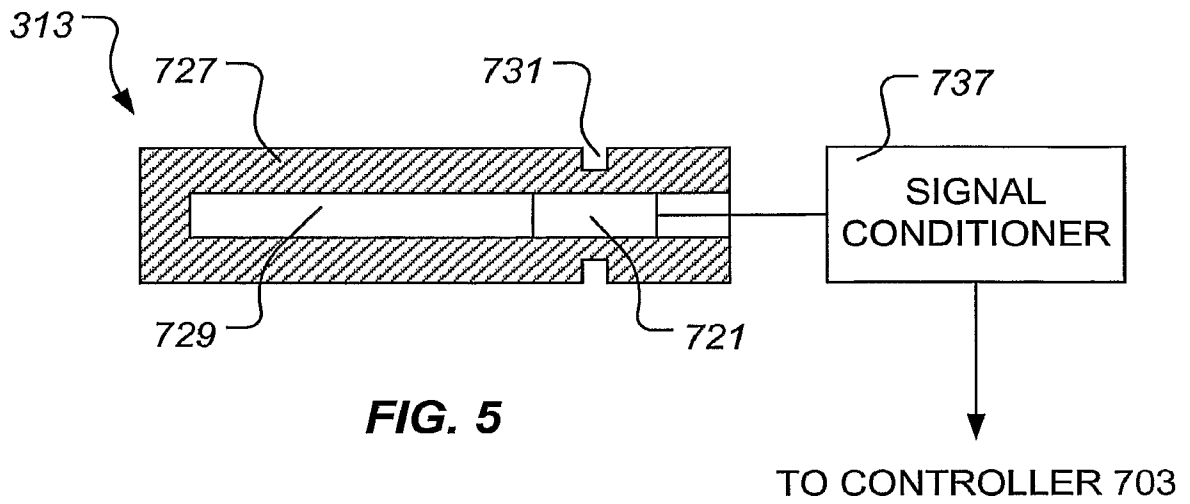


FIG. 6

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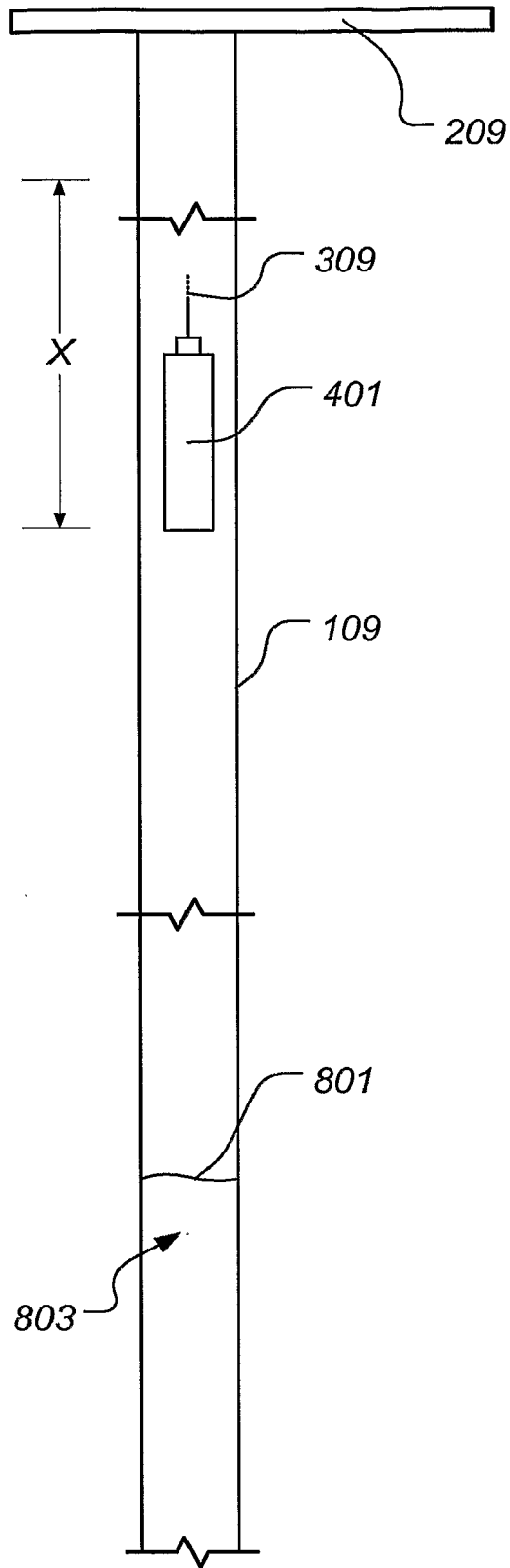


FIG. 7A

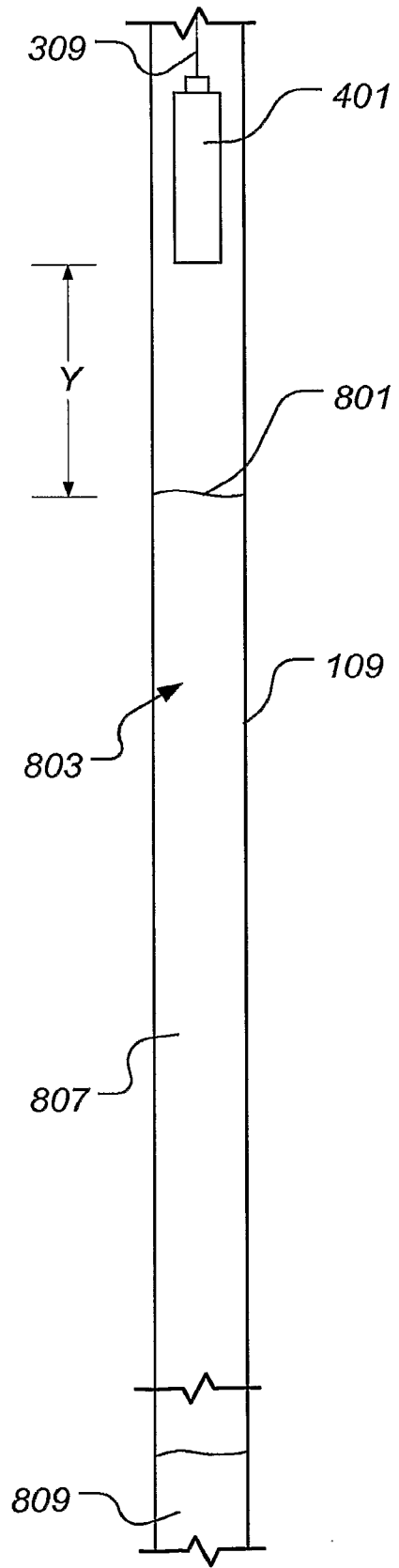


FIG. 7B

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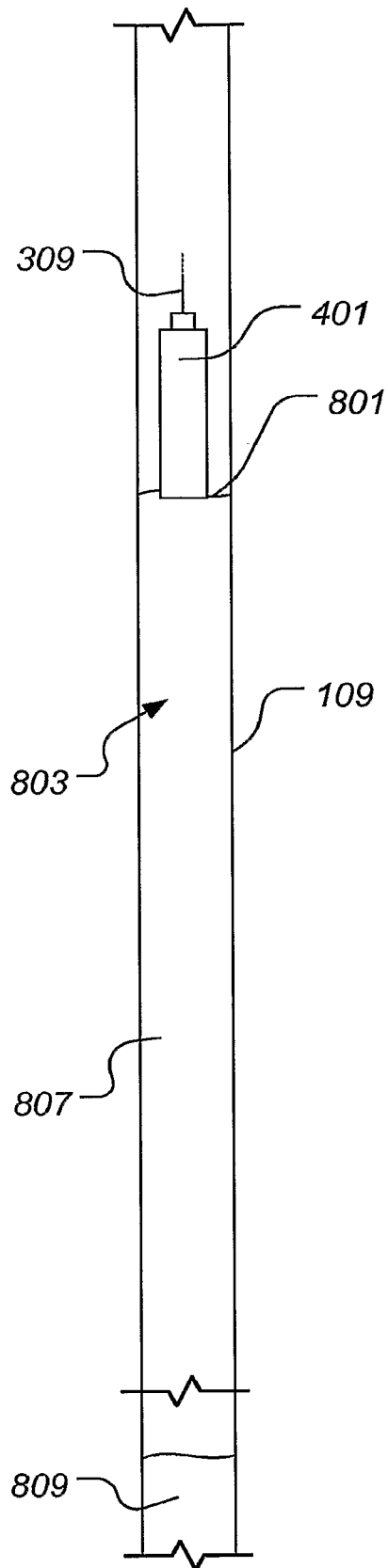


FIG. 7C

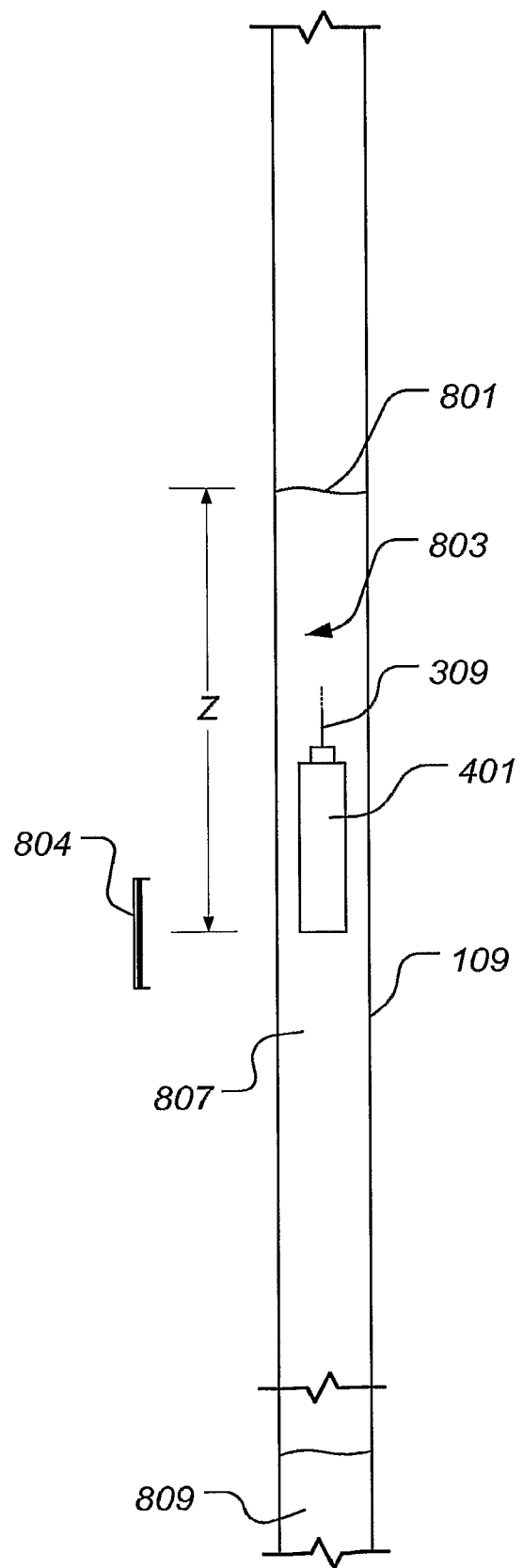
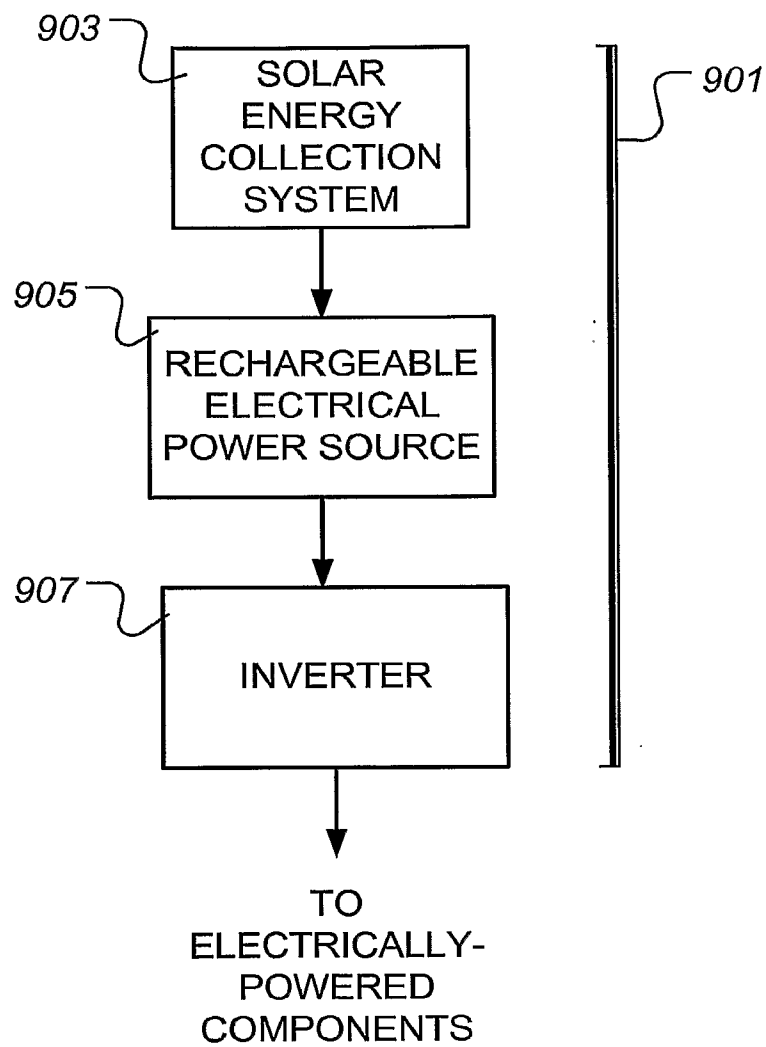


FIG. 7D

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**FIG. 8**

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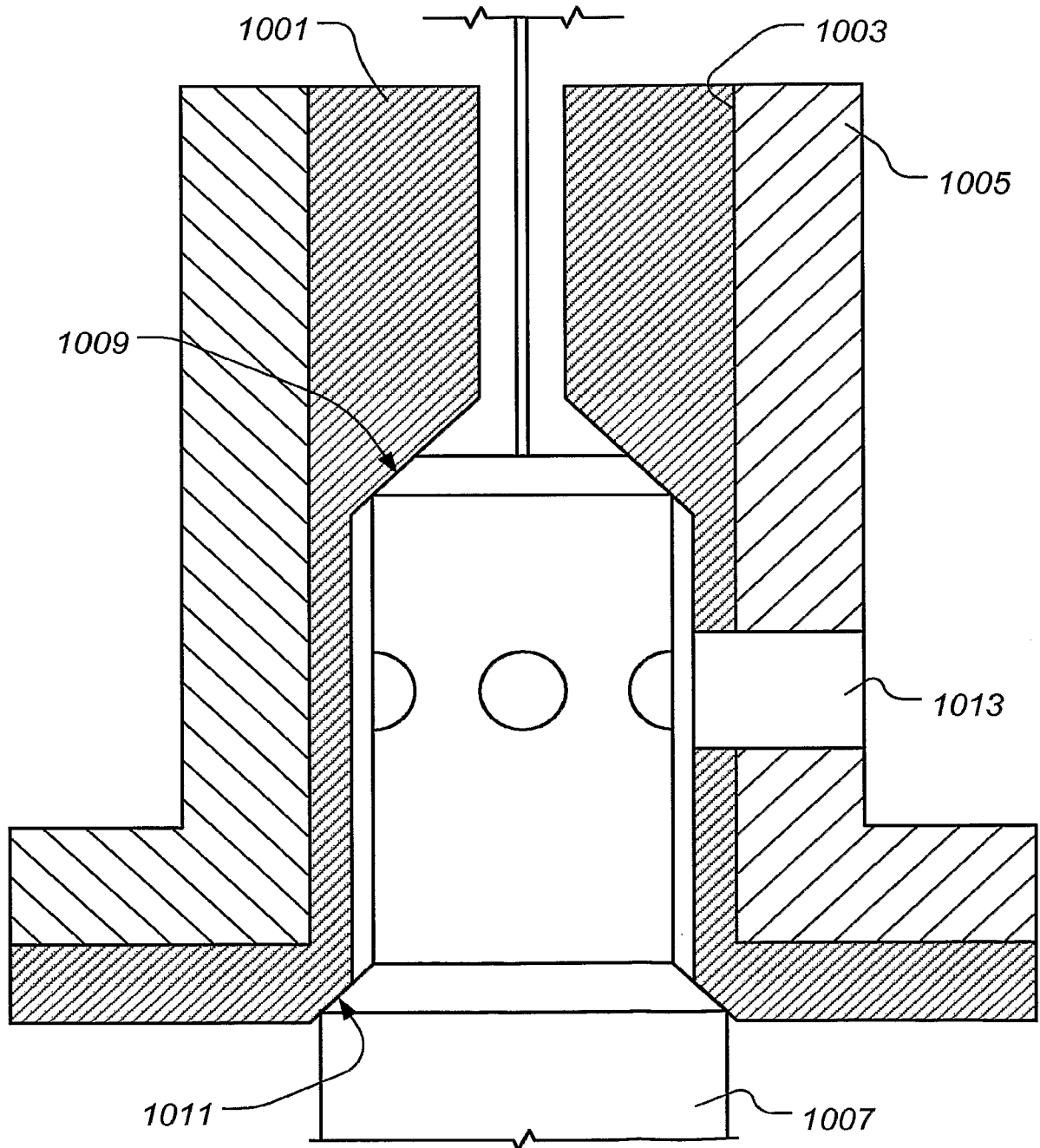
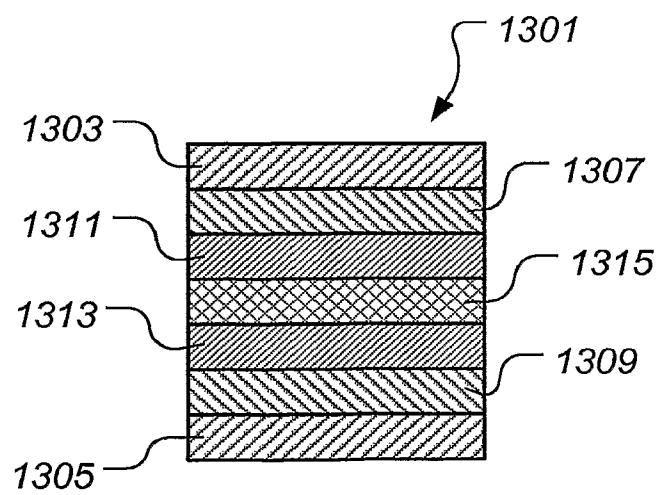
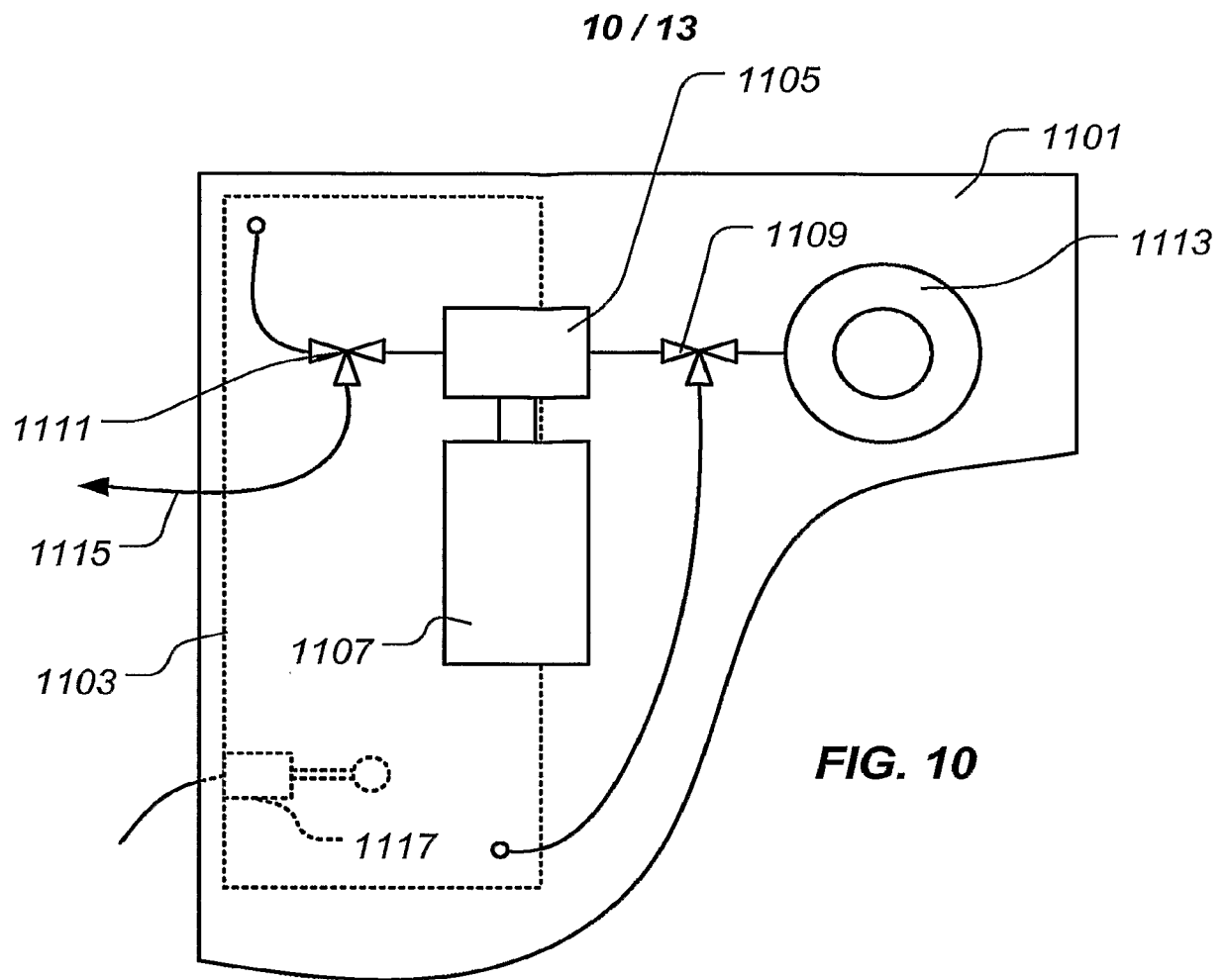


FIG. 9

**FIG. 12**

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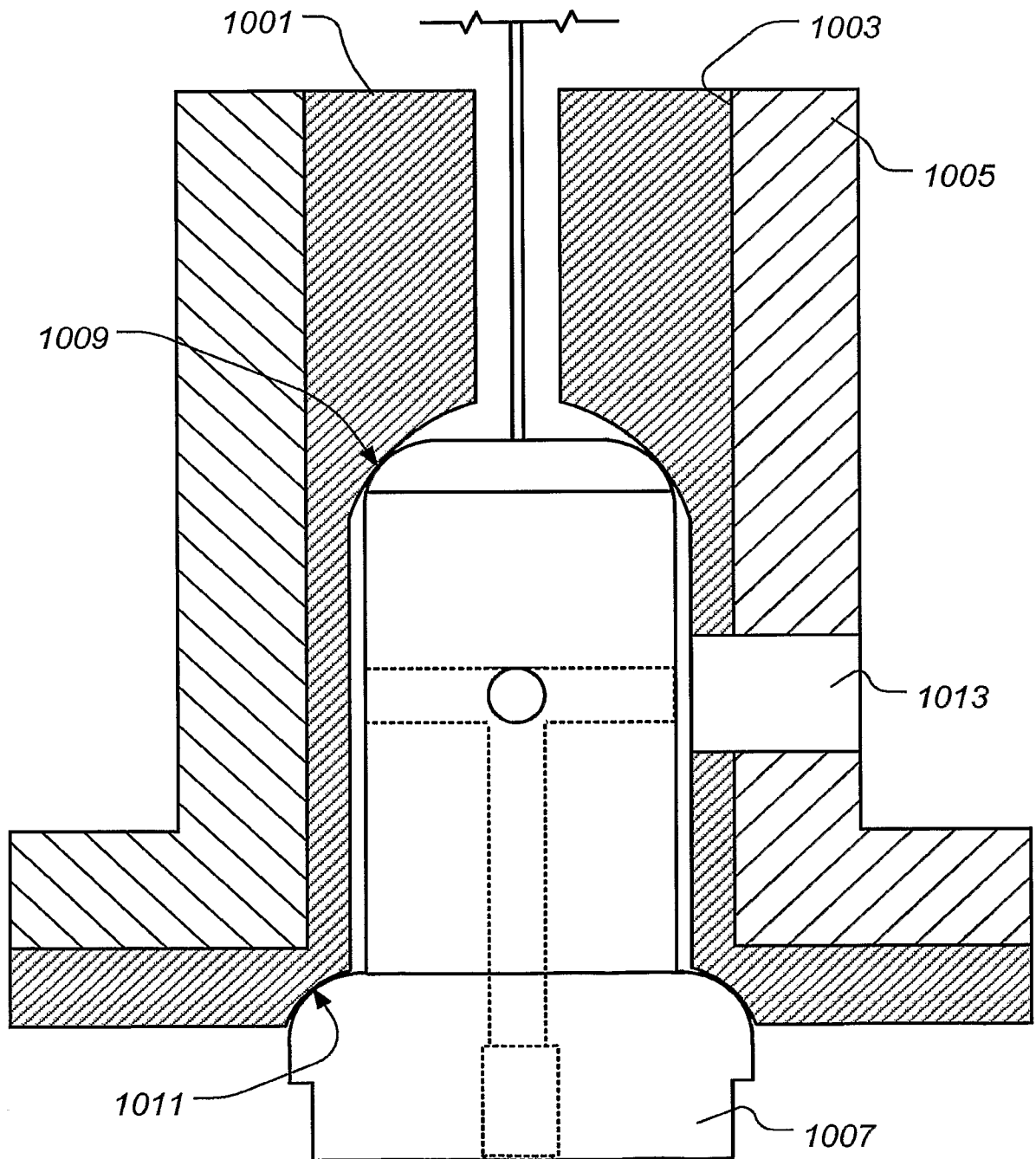
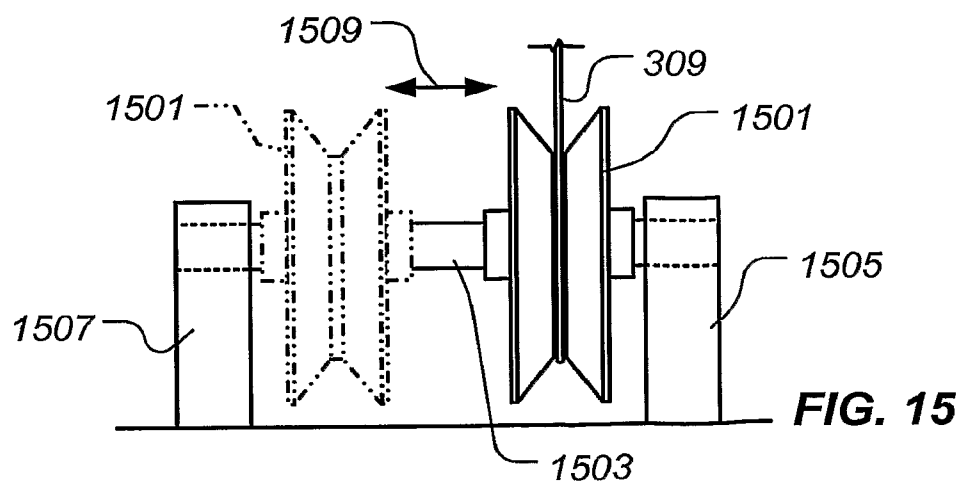
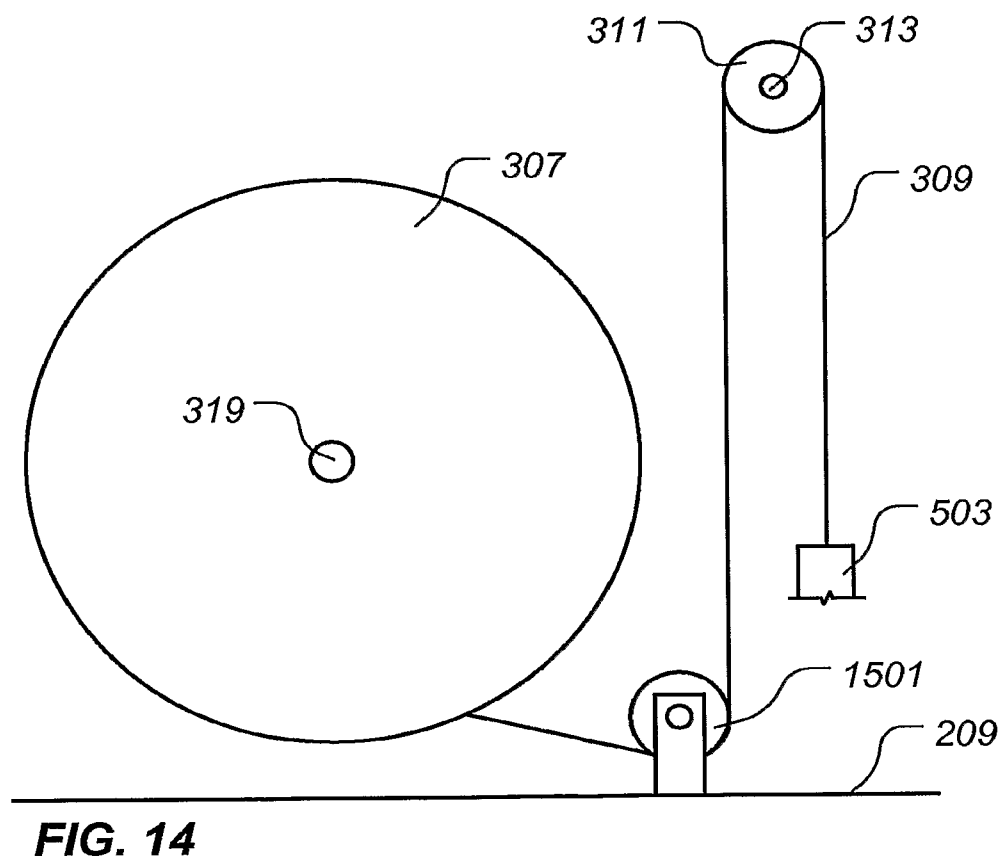
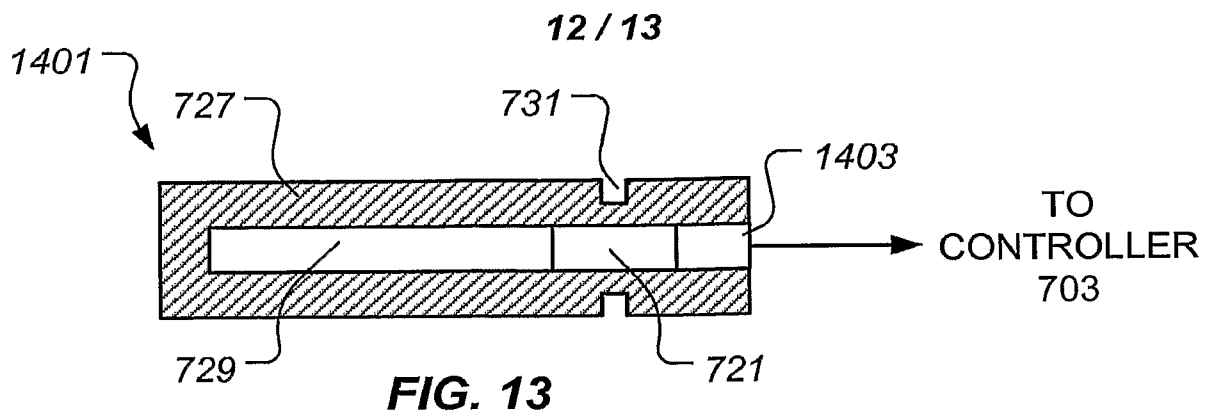


FIG. 11



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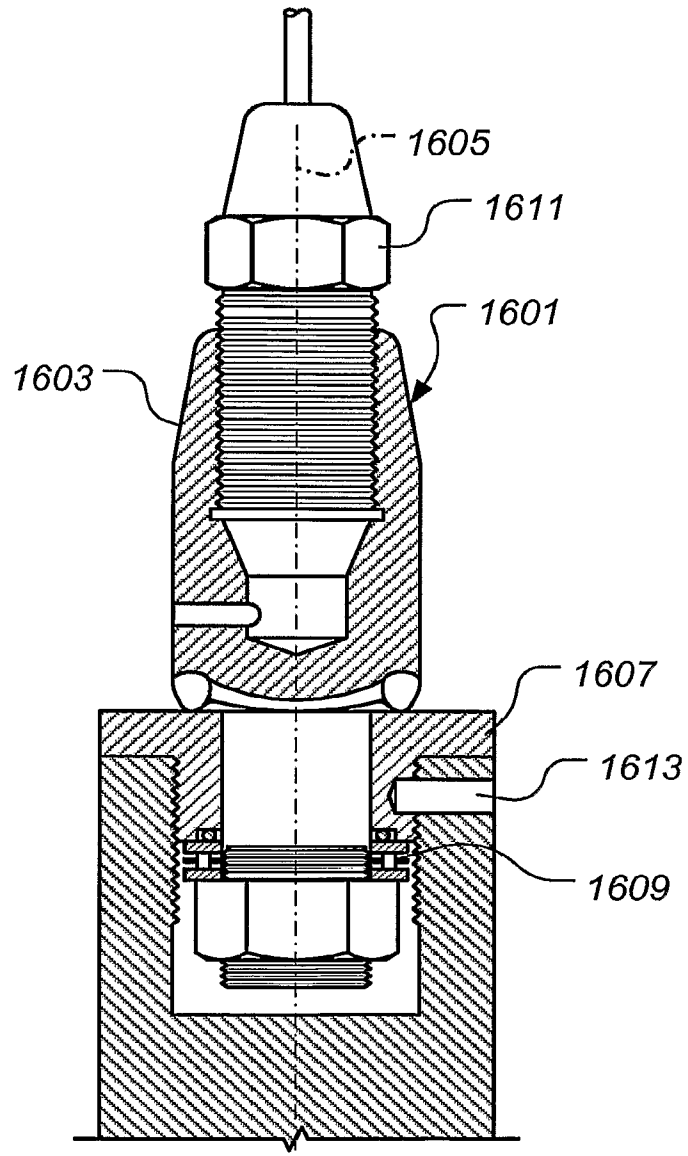


FIG. 16