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(54) HYDRAULICALLY OPERATED WELLBORE LIQUID LIFT USING CASING GAS AS ENERGY SOURCE

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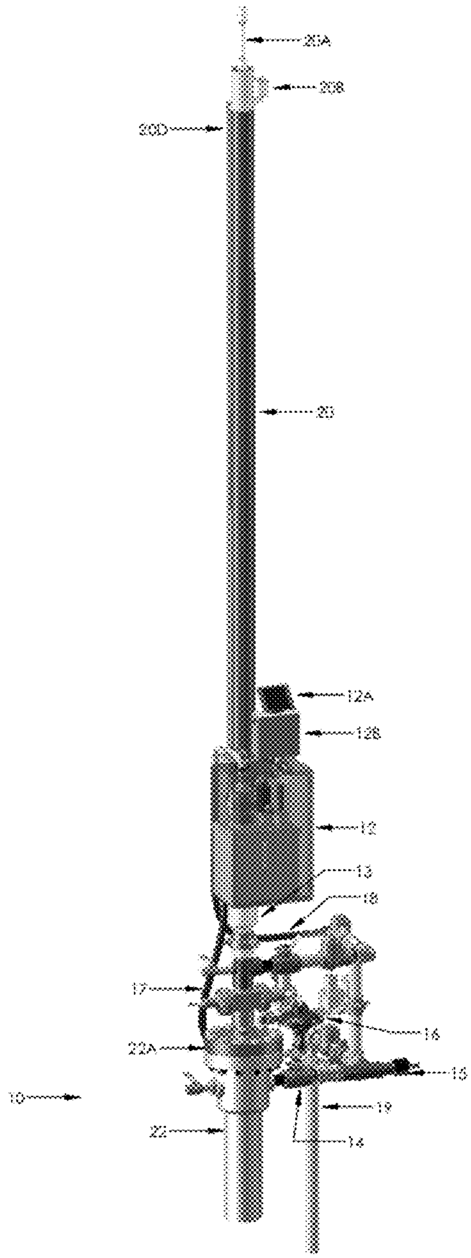
(57) **ABSTRACT**

A system for lifting liquid from a wellbore includes a turbine selectively coupled to a source of gas flow originating in the wellbore. The turbine is arranged to convert the gas flow directly into rotation of the turbine. An hydraulic pump is rotationally coupled to the turbine. An hydraulic cylinder and piston are arranged to move a sucker rod string disposed in the wellbore. Control valves are provided to selectively apply gas flow to the turbine and hydraulic pressure from the pump to lift the piston and enable lowering thereof by the weight of the sucker rod string. The system further comprises control circuits configured to operate the control valves.



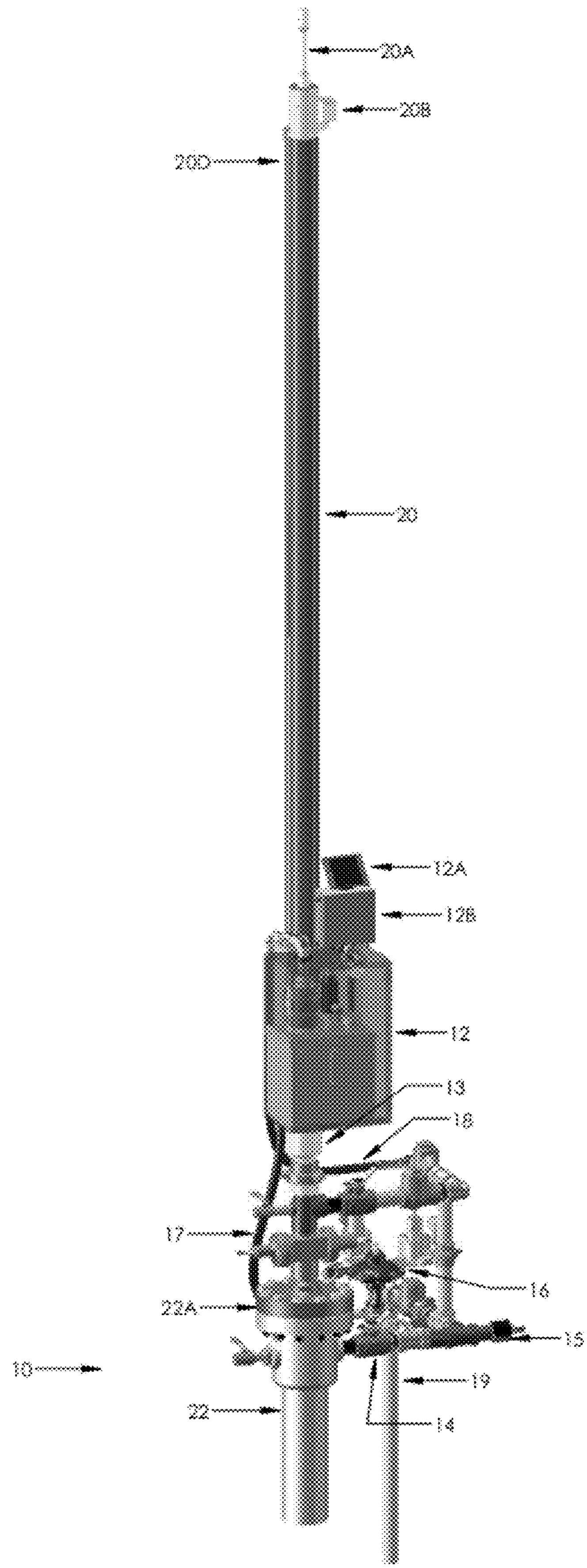


FIG. 1

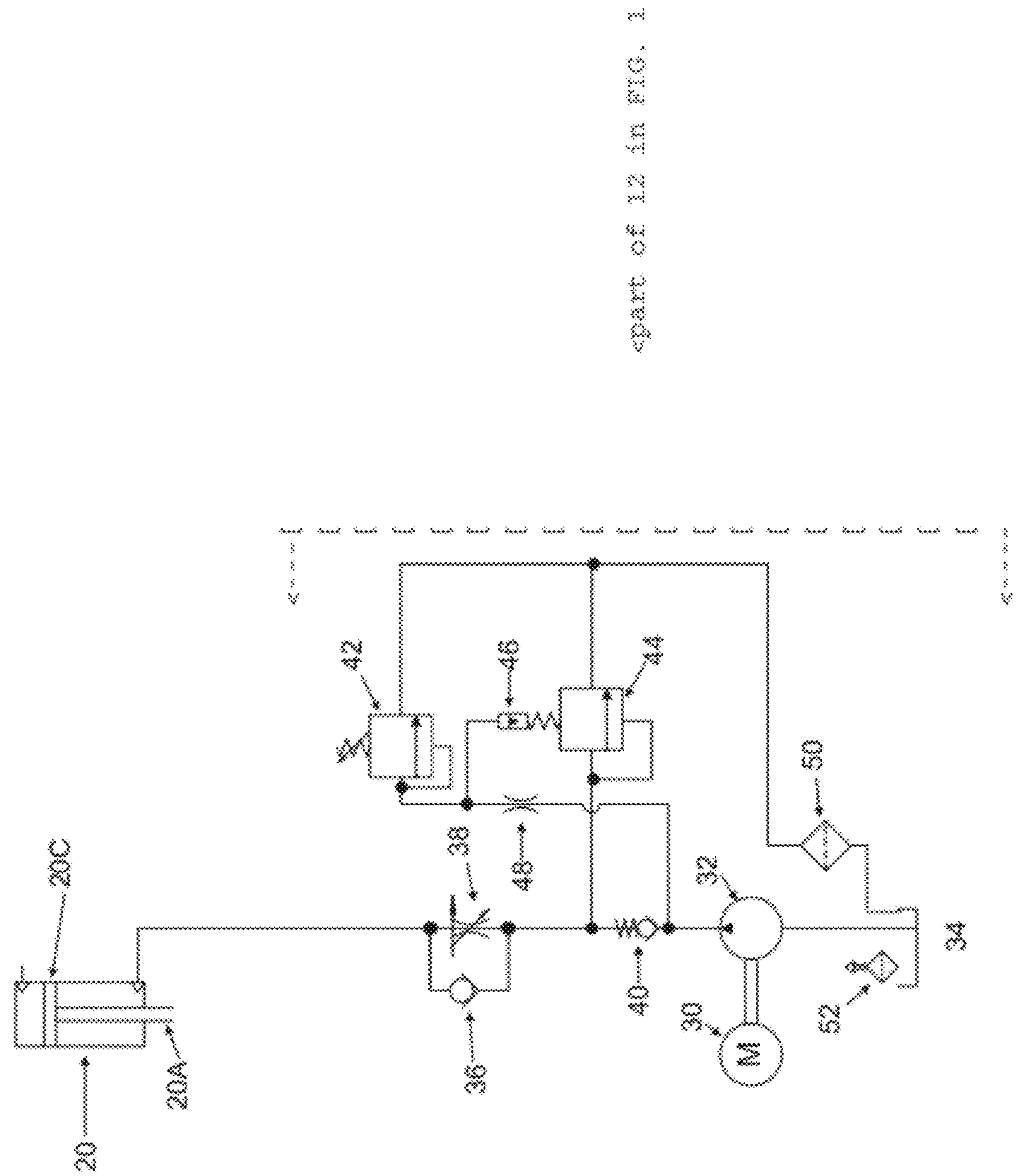
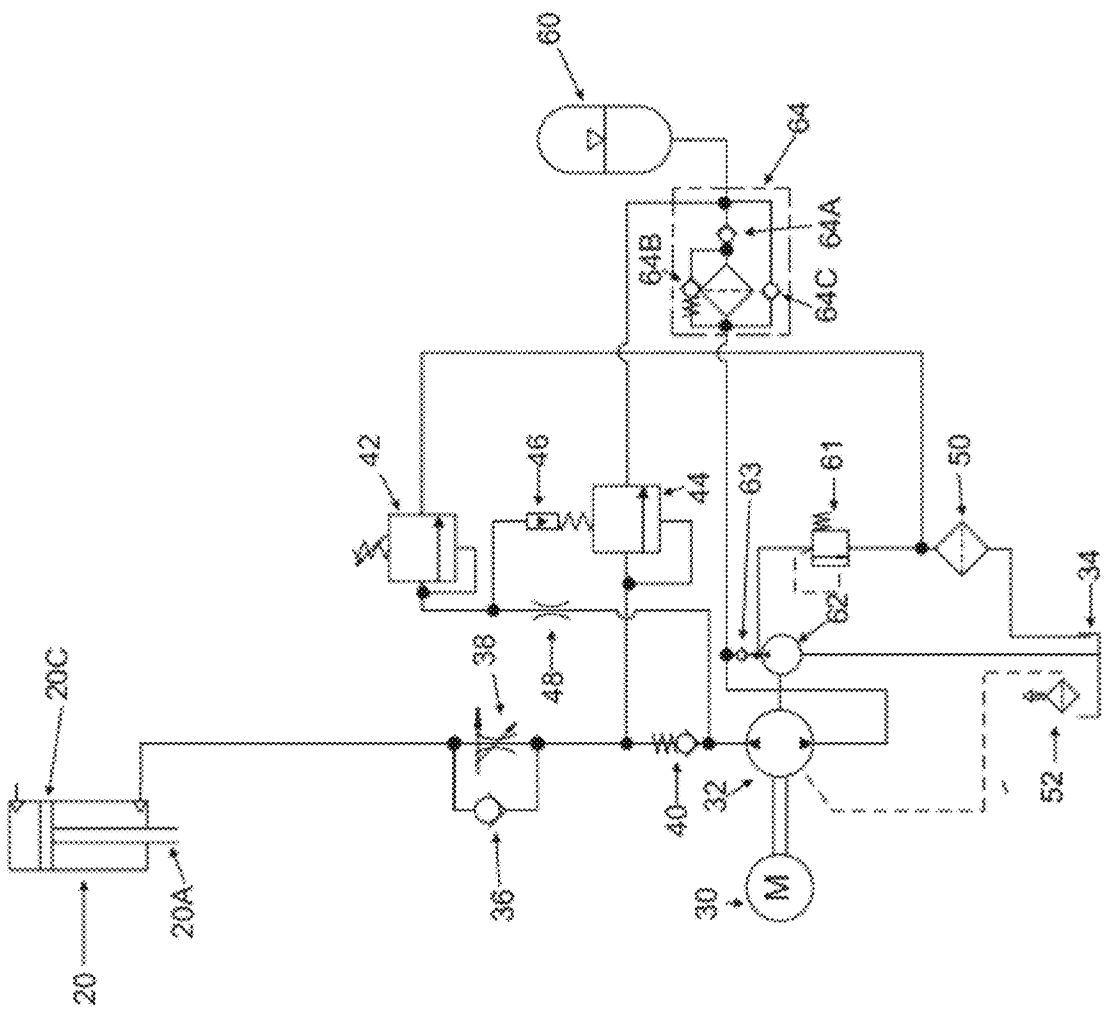


FIG. 2

FIG. 3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HYDRAULICALLY OPERATED WELLBORE LIQUID LIFT USING CASING GAS AS ENERGY SOURCE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

BACKGROUND

[0003] The invention relates generally to the field of removal of liquid from gas producing subsurface wellbores. More particularly, the invention relates to energy sources to operate hydraulic cylinder liquid lifting devices for removal of liquid from such wellbores.

[0004] The oil and gas industry has undergone rapid development in the number of wells drilled for natural gas production from "shale" reservoirs. The number of such gas producing wellbores has increased the need for improved means for deliquification (removal of water) of these wells with typical liquid production rates and depths to as much as 12,000 (can we do 14,000 ft??) feet.

[0005] Hydraulically operated vertical lift cylinders attached to the "wellhead" (control valves and related components at the surface to control fluid flow into and out of the wellbore), like that of electrically or gas engine powered "pump jacks" (reciprocating beam operated sucker rod pumps), provide advantage in many situations due to the incremental stroking of the plunger pump to cause liquids to rise more steadily in a production tubing disposed within the wellbore "casing" (a protective pipe extending to proximate the bottom of the wellbore and typically cemented in place). The action of hydraulic lift cylinders for rod pump well deliquification overcomes a disadvantage common to plunger lift apparatus which tends to release a larger burst of liquid when moved upwardly in the well bore and with such liquid volume comes associated gas. Such large volumes of liquid and gas released in a short time may cause the need for larger separation equipment, and sufficiently large surges of liquid and gas may disturb gas compressor operation.

[0006] Large surges of gas negatively affect compressor intake conditions, control and performance, whereas it can be appreciated that much more attractive and steady flows of both natural gas and liquids are enabled using hydraulic lift cylinder deliquification apparatus.

[0007] It is known in the art to use internal combustion (IC) engines to use a portion of the natural gas being produced from a wellbore to power a conventional beam pump jack. However, this method of producing the well has come under increasing regulatory scrutiny, and more stringent requirements for a well operator to use costly emissions certified IC engines, purchase and maintain IC engine exhaust gas treatment equipment, and costly time-consuming application for and maintenance of air emissions permits has made such wellbore deliquification techniques less attractive economically. In some geographic areas, for example California and the Texas Houston air quality attainment district, increased regulatory scrutiny and likely additional burdens will be placed on oil and gas well operators within a relatively large geographic areas.

[0008] Gas and oil wells tend to decline in production over time, and some even increase liquid (particularly water) production relative to natural gas, natural gas condensate and crude oil, the commonly valued constituents of producing the petroleum well.

[0009] The industry's commonly accepted threshold limit for producing natural gas and oil wells with the plunger lift method is described, for example, in E. Beauregard, et al., Introduction to Plunger Lift: Applications, Advantages and Limitations, Presented at The Southwestern Petroleum Short Course, Department Of Petroleum Engineering, Texas Tech University, Lubbock, Tex., Apr. 23-24, 1981. As can be appreciated, when the plunger lift method of production will no longer suffice, the oil and gas well operator has previously been faced with having to provide electricity or burn a portion of his produced hydrocarbons in an IC engine to provide the power to operate a sucker rod pump to lift the liquids from the wellbore.

[0010] There exists a need for wellbore deliquification devices that do not require the use of external power sources, such as electricity and/or IC engines.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** shows an example installation of a deliqufication apparatus.

[0012] FIG. **2** shows example hydraulic control circuits for the system of FIG. **1**.

[0013] FIG. **3** shows a modified form of the example shown in FIG. **2**.

DETAILED DESCRIPTION

[0014] The present invention provides a device and method to be able to produce hydrocarbons from wellbores previously unable to be produced as a result of excessive liquid production in cases where electricity is unavailable or costly to install to the site. Although electricity installation to wellsite would alleviate the air emissions burden, many wells are located either far from electricity access or where grid electricity access is difficult and costly. Since many wells have declined below the ability to naturally flow as a normal progression in mature production decline, large numbers of wells exist where no grid electricity connection has been provided to the wellsite and the costs of installing it are a substantial burden to profitable production of the well.

[0015] The present invention may also provide wellbore operators with the ability to operate a sucker rod pump to remove liquid from wells to maintain and in many cases increase production, with no burning of a portion of produced natural gas, nor any costly, time-consuming requirement to seek regulatory approval for air emissions permit for IC engines, and thereafter the cost and maintenance associated with operating the IC engine to the U.S. Environmental Protection Agency and any state regulatory air emissions standards.

[0016] FIG. **1** shows an example wellbore liquid lift installed on a wellbore. The wellbore terminates at the surface at the upper end of a wellbore casing **22**. A casing head **22**A may be used to seat therein a tubing hanger and production tubing (neither shown in FIG. **1** for clarity), wherein the production tubing is disposed inside the casing **22**. The casing **22** may include a discharge port and associated control valve, shown at **14**, for venting natural gas pressure that accumulates in annular space between the tubing (not shown) and the wellbore casing **22**. Some of the vented gas may be transferred through a line **19** to processing equipment (not shown in FIG. **1**) to separate water to disposal, hydrocarbon liquids for sale and natural gas for eventual compression and transmission to a gas transmission pipeline (not shown).

[0017] Flow and pressure of the gas from the casing **22** may be controlled using a control/regulation valve **16**. The pressure and flow regulated gas may be transferred through a hose or piping **17** to a power conversion unit **12**. The power conversion unit **12** uses flow of natural gas from the wellhead connection (discharge port **14**) to operate a turbine (**30** in FIG. **2**), the rotation of which may be used to operate an hydraulic pump (**32** in FIG. **2**). The foregoing components will be further explained with reference to FIG. **2**. The power conversion unit **12** may include control circuitry **12**B including, for example, a microcontroller (not shown separately) to operate the gas control valve **16**, and/or hydraulic valves as will be further explained with reference to FIG. **2**. Electrical power for the power conversion unit circuitry **12**B may be provided by batteries and/or solar panels **12**A.

[0018] Hydraulic power provided by the power conversion unit **12** may be used to operate an hydraulic lift cylinder **20**. The lift cylinder **20** may be connected to the uppermost portion of the casing **22** with a wellhead connection having an hydraulic oil port, shown generally at **13**. The hydraulic lift cylinder **20** may raise and lower a sucker rod string **20**A. The sucker rod string **20**A may be coupled at its lower end to a conventional wellbore fluid lift pump, including, for example, a standing valve and traveling valve therein (not shown in the figures). During operation, the power conversion unit **12** provides hydraulic pressure to cause the hydraulic cylinder **20** to lift the sucker rod string **20**A. When the sucker rod string **20**A reaches a predetermined upper travel limit, a switch **20**B may operate to send a signal to the control circuitry **12**B to allow controlled dropping of the sucker rod string **20**A within the hydraulic cylinder **20** by release of hydraulic pressure therefrom.

[0019] In other examples (not shown) where desirable, the cylinder **20** could also be mounted at lower portion on a pedestal spaced above the wellhead and coupled to the top of a conventional polished rod; the cylinder/rod coupling would remain above a conventional stuffing box throughout its stroke. An adjustable setting spring over ball backpressure valve is shown at **15**. Such valves are commonly used to hold a backpressure on either the tubing outlet or the casing outlet **14**. Such valve **15** may be used in the present configuration to direct all flow of gas from the casing outlet **14** to the turbine (**30** in FIG. **2**) up to a certain pressure, for example 100 to 150 pounds per square inch. Pressure exceeding the setpoint opens the valve **15** and it then releases the gas being produced by the well in excess of what the turbine needs to go downstream to processing, possible compression and to a pipeline as explained above.

[0020] FIG. **2** shows an example turbine powered hydraulic unit to operate the hydraulic cylinder and sucker rod shown in FIG. **1**. A turbine **30** is disposed in the flow of gas from the casing **22** as explained with reference to FIG. **1**. The turbine **30** is rotated by the movement of the gas, and such rotation may be coupled to an hydraulic pump **32** which draws fluid such as hydraulic oil from a reservoir **34**. When it is desired to lift the sucker rod string **20**A, the control circuitry (**12**B in FIG. **1**) may open the control valve **16** to enable turbine rotation and consequent pump **32** rotation, thus pressurizing hydraulic fluid to flow into the hydraulic cylinder **20** to lift the sucker rod string **20**A by applying hydraulic pressure under a piston **20**C connected to the rod string **20**A. When the rod string **20**A reaches the upper limit of its travel, the switch (**20**B in FIG. **1**) may close and cause the circuitry (**12** in FIG. **1**) to close the gas supply control valve **16**. The flow of gas from wellhead casing annulus ceases, as does then turbine rotation and hydraulic pump rotation. A check valve **36** causes the flow of hydraulic oil from out of the cylinder **20** (caused by the weight of the rod string **20**A) to be directed through a controllable orifice valve **38**, which may be manually or otherwise set to enable the rod string **20**A to drop at a practical, optimal descent rate according to the well pumping conditions. In another example, both the controllable orifice valve **38** and the gas supply valve **16** can be configured to be in signal communication with the control circuitry **12**B so that the rate of upstroke lift and downstroke drop of the sucker rod string **20**A may be controlled to optimum benefit, and the control circuitry **12**B may be organized to be in remote communication via any wired or wireless communication technique known in the art.

[0021] Shown at **44** is a pilot operated and adjustable set point (**46** being the set point adjustment knob) pressure relief valve. Turning the knob **46** changes the spring pressure on the relief valve **44** to obtain a selected relief pressure. By addition of pilot components including an orifice **48** and a pilot valve **42** , the relief valve **44** can also be used to open and let the hydraulic oil return on the downstroke out of the hydraulic cylinder **20** through the relief valve **44** into a filter **50** and ultimately into the supply reservoir **34**. The hydraulic fluid flow is checked at the hydraulic pump **32** outlet (by valve **40**) to prevent reverse rotation of the hydraulic pump **32**. By further explanation, by re-directing the internal pilot line located upstream of the check valve **40**, the relief valve **44** opens by reduced pressure at the pilot. Hydraulic fluid then returns through the filter **50**. The function occurs due to the position of sourcing pilot pressure port holding the valve **44** closed, (in conjunction with internal pilot valve balance spring) for the duration of time the hydraulic pump **32** operates to lift the sucker rod **20**A. When the upstroke lift has been completed, and the control circuitry **12**B turns off the gas flow to the turbine **30**, the pressure on the pump side of the check valve **40** drops and the relief valve **44** opens, letting returning hydraulic oil out of the cylinder **20** and ultimately into the reservoir **34**.

[0022] The upper portion of the hydraulic cylinder **20** located above the piston **20**C may be filled with hydraulic fluid. The flow of hydraulic fluid out of and into the upper portion may flow through a fluid conduit **20**D in fluid communication with the reservoir **34**. Such configuration may be preferred to accomplish several beneficial functions. The first is to provide for more stable hydraulic oil volume in the reservoir **34**; this also facilitates minimal reservoir level change in the reservoir **34** from the upstroke to the downstroke. Another possible benefit is minimizing outside air and moisture exchange through a reservoir breather **52**. Further, cooling of the hydraulic oil is facilitated with the cylinder **20** releasing heat from the oil contained therein to the outside air, since in many installations the sucker rod string **20**A can remain in its downward most position and at rest a substantial portion of the time. Any seepage past piston **20**C seals may also be returned to the reservoir **34** because the hydraulic cylinder **20** is hydraulically closed at both ends. The cyclic influx and discharge of hydraulic fluid may clean and lubricate the piston/cylinder interface for longer service life.

[0023] FIG. **3** shows a modified form of the example shown in FIG. **2**, with the addition of an accumulator arrangement useful for purposes of energy conservation that may be particularly useful when the system is used in deeper wells. The function of the accumulator **60** is to offset, or balance part or all of the sucker rod string lift load. The sucker rod string **20**A may be made, for example, from steel and may weigh approximately 1.5 lbs per foot; thus a 10,000 foot length sucker rod string would weigh approximately 15,000 pounds. In such example a 4.00 inch bore diameter cylinder with a 1.5 inch diameter piston rod coupled to the sucker rod string would require (15,000/10.8) 1389 pounds per square inch pressure applied under the piston **20**C in the hydraulic cylinder **20** to balance the weight of the sucker rod string **20**A of this example. In practice, only a portion of the total hydraulic fluid pressure required to offset the full weight of the sucker rod string **20**A will be used. The particular portion may be chosen according to the particular well conditions, thus to generally maintain a sucker rod string positive weight bias, yet reduce casing head gas and energy consumption by almost half. A piston type accumulator may be preferred, with additional accumulator pressure bottles provided as needed, but the accumulator **60** can also be of the bladder type, where a gas exerts force on hydraulic fluid through a flexible barrier or membrane. The pump **32** receives this hydraulic fluid under pressure to its suction port from the accumulator **60**, reducing the energy required to be exerted by the pump **32** to lift the sucker rod string **20**A. A filter **64** may be used to remove contamination from the hydraulic fluid and may be configured in a manner to prevent contaminants collected therein from being re-entrained when the hydraulic fluid direction through the filter **64** is reversed. Upon completion of sucker rod lift, the relief valve **44** opens to return the hydraulic fluid under pressure to the accumulator **60**, preserving energy for the next sucker rod lift cycle. Pump shaft seal and/or pump case drain hydraulic fluid seepage losses that may result from the pressure imparted by the accumulator **60**, pump and cylinder circuit can be directed to a vent to the reservoir **34** and may be re-introduced to the pressurized hydraulic circuit by a charge pump **62** through a check valve **63**. An adjustable relief valve **61** may mediate the reintroduction of hydraulic fluid according to the relationship of its pressure setting to the lowest point of pressure exerted by the accumulator **60** on the pump **32** intake when the cylinder **20** has lifted the sucker rod **20**A to its highest position. The adjustable relief valve **61** also acts to protect the charging circuit from over-pressure conditions.

[0024] While the example embodiments explained above with reference to FIGS. **1-3** show the hydraulic cylinder and piston being directly coupled to the sucker rod string, it will be appreciated by those skilled in the art that the above described system could also be used in versions of reciprocating beam pump units (pump jacks) that are operated by selective expansion and contraction of an hydraulic cylinder and piston combination. In still other examples, rotation of the turbine may be converted by devices known in the art to cause reciprocating motion of the beam in such pump jacks, e.g., gearing and rotating pitman arms or cranks.

[0025] A system and method according to the various aspects of the invention may use flow of natural gas out of a wellbore converted directly into mechanical energy to operate a liquid lift pump in the wellbore without the need for external sources of energy, such as electricity, or without the need to consume the gas to release its chemical energy (e.g., by internal combustion or catalytic conversion.

[0026] While the invention has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the attached claims.

What is claimed is:

1. A system for lifting liquid from a wellbore, comprising:
a turbine selectively coupled to a source of gas flow originating in the wellbore, the turbine arranged to convert the gas flow directly into rotation of the turbine;
an hydraulic pump rotationally coupled to the turbine;
an hydraulic cylinder and piston arranged to move a sucker rod string disposed in the wellbore;
control valves to selectively apply gas flow to the turbine and hydraulic pressure from the pump to lift the piston and enable lowering thereof by the weight of the sucker rod string; and
control circuits configured to operate the control valves.

2. The system of claim **1** wherein the control valves comprise a gas supply control valve to cause turbine rotation when the sucker rod string requires lifting.

3. The system of claim **1** wherein the control valves comprise a controllable orifice valve in a line connecting the hydraulic cylinder to a reservoir, the controllable orifice valve arranged to enable lowering of the sucker rod string at a selected rate.

4. The system of claim **1** further comprising an accumulator in hydraulic communication with an intake side of the hydraulic pump, the accumulator charged to a selected pressure and configured to recharge using hydraulic fluid displaced from the cylinder when the sucker rod string is allowed to drop.

5. A method for lifting liquid from a wellbore, comprising:
converting flow of gas from a wellbore directly into rotational energy using a turbine disposed in the gas flow;
converting the rotational energy into reciprocating motion; and
using the reciprocating motion to operate a sucker rod string disposed in the wellbore.

6. The method of claim **5** wherein the converting rotational energy comprises rotating an hydraulic pump, and selectively directing pressure output from the hydraulic pump to an hydraulic cylinder/piston combination coupled to the sucker rod string.

7. The method of claim **6** further comprising stopping rotation of the hydraulic pump, and selectively controlling rate of discharge of hydraulic fluid from the cylinder/piston combination to enable dropping the sucker rod string at a selected rate.

8. The method of claim **6** further comprising prepressurizing the pump with pressure stored in an accumulator to at least partially offset a weight of the sucker rod string.

9. The method of claim **5** wherein the flow of gas from the wellbore is from an annular space between a wellbore casing and a wellbore tubing disposed within the wellbore casing.

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