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(54) Title: HYDRAULIC OILFIELD LIFT PUMP

(57) Abstract: A vertically orientated hydraulically driven oilfield lift pump unit having a simplified hydraulic system. The system uses a pair of single acting hydraulic cylinders in tandem with a pair of double acting hydraulic cylinders interacting with hydraulic accumulators to provide an energy efficient, robust hydraulic system design with a minimum number of components.

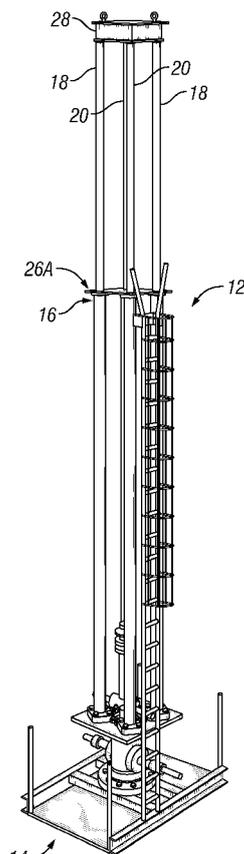


FIG. 2



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HYDRAULIC OILFIELD LIFT PUMP

This application claims priority from United States provisional patent application
5 Serial No. 61/183,264, filed on June 2, 2009, which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention.

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This invention relates to lift pumps suitable for producing hydrocarbons and other liquids from the earth. In particular, this invention is drawn to a very long stroke hydraulically operated lift pump using a combination of single and double acting hydraulic cylinders that are actuated with an energy efficient hydraulic fluid accumulator system.

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2. Description of the Related Art.

Hydraulically operated Oilfield lift pumping units are well known and have been used in the industry for many years. Typically, these units mimic the non-hydraulic mechanical
20 'walking beam' design similar to the pumping unit 10 illustrated in Figure 1. These conventional units are more commonly driven directly by electric motors through gear boxes, but many are also hydraulically driven as shown for example in U.S. Patents 4,201,115; 4,198,820; 3,405,605. These hydraulic units are typically configured similarly to the motor driven units, but have hydraulic cylinders fitted in place of the linkages and
25 gearing of the mechanical system.

Limitations of the 'walking beam' design include limited stroke variability, the need for a rotating counter weight of roughly the same weight as the sucker rods and other devices suspended in the borehole, and a stroke limited by the length of the 'walking beam' and/or
30 the height above the ground of the mast upon which the beam is mounted.

Nonetheless, these 'walking beam' pumps are ubiquitous in the industry and are readily visible from many major thoroughfares, particularly in Texas and western Canada.

Vertical pumping units, as shown for example in U.S. Patents 4,761,120; 4,512,149; 4,698,968; 4,762,473, typically use hydraulic cylinders aligned vertically which typically connect directly to the sucker rod string and are controlled by complex hydraulic systems. These vertical systems have attempted, and often times succeeded in overcoming many of the above mentioned limitations. However, these units tend to have very complex hydraulic systems because the mechanical design requires the hydraulic system to perform many different functions. Furthermore, these units also tend to have very uneven power cycles, causing a very cyclic loading on the prime mover, and requiring it to have a much higher horsepower rating to power through the peak loads, than the overall average horsepower consumed.

BRIEF SUMMARY OF THE INVENTION

Described herein is a new type of hydraulically driven oilfield lift pump unit which features a simplified hydraulic system. This system comprises a hydraulic power section and a wellhead mounted lifting section. The hydraulic power section is typically, but not limited to, a flow controlled, pressure compensated hydraulic pump system that can readily be optimally sized to meet the desired lifting speed and weight parameters of the lift section and an electrically controlled 4-way type variable displacement control valve, or other types of suitable control valves. These types of 'power units' are well known and are in common use in the industry.

The lifting section comprises a plurality (typically a pair) of single acting hydraulic cylinders, and a plurality (typically a pair) of double acting hydraulic cylinders. The cylinders are mechanically mounted on common end plates such that they all must extend and retract simultaneously.

The cap ends of the double acting cylinders are 'closed-coupled' to one or more hydraulic accumulators so that in normal operation all the flow into and out of the cap ends of the cylinders is into or out of the hydraulic accumulators. The accumulators are pre-charged with gas at a pressure such that when the cylinders are fully extended and the accumulators nearly depleted of hydraulic fluid, the double acting cylinders are nonetheless able to statically hold a high percentage, of the lifting load.

This may also effectively balance the pump motor's load between the upstroke and the downstroke cycles, and may permit use of a prime mover motor or engine to run under a relatively constant load (compared to conventional pumps) regardless of whether in both the upstroke mode and the downstroke mode. Typical load variations may be in the range of 70% to 130% of the average load, but as will be described, these variations may be reduced even more than this, if desired. When compared to other pump units of this type, the load balancing effect of the accumulators allows the use of a motor with a significantly less horsepower rating (or capacity) than the prior art units. Furthermore, the lower peak power consumption may allow for a lower effective electric rate, as in many locations the electric rate is based on, or at least affected, by the peak load instead of the average load.

During the "up" stroke, pressurized fluid from the hydraulic power unit is applied only to the 'cap' ends of the single acting cylinders, causing all of the cylinders to extend together. The pair of single acting hydraulic cylinders can only be powered in the extended direction. The pressure required to operate the single acting cylinders will steadily increase as the cylinders extend because the lifting capability of the double acting cylinders decreases as the accumulators gas volume expands. In the preferred embodiment, the load on the down stroke may typically be about two-thirds of the load on the up stroke. This difference is caused by a transfer of fluid column weight onto the down hole lifting valves.

During the 'down' stroke, the pressurized fluid from the hydraulic power unit is applied only to the 'rod' ends of the double acting hydraulic cylinders. The combination of the weight of the load and this hydraulic pressure on the top end of the cylinder causes all the cylinders to retract. This in turn forces the hydraulic fluid on the cap ends of the double acting cylinders back into the accumulators – and therefore filling them. The relative horsepower required for each of the 'extend' and 'retract' cycles may be changed and/or more nearly equalized by adjusting the pre-charge pressure of the accumulators to account for variations in the average lifting load, permitting usage of the smallest possible engine or motor for the hydraulics. Furthermore, this may also help reduce large load fluctuations, reducing stress on the system. However, because in some instances the actual loading may vary over time, an intermediate pre-charge pressure may be chosen.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is side view of a typical ‘walking beam’ oilfield lift pump of the prior art.

5 Figure 2 is an overall perspective view of the oilfield lift pump of the present invention.

Figure 3 is a perspective view of just the mast section of lifting section of the oilfield lift pump of the present invention.

10 Figure 4 is a hydraulic schematic diagram of the hydraulic power unit of the present invention.

Figure 5 is a portion of the hydraulic diagram of the lifting portion of the lifting portion of the oilfield pump of the present invention showing the hydraulic flow arrangement for the
15 “up stroke” portion of the pumping cycle.

Figure 6 is a portion of the hydraulic diagram of the lifting portion of the oilfield pump of the present invention showing the hydraulic flow arrangement for the “down stroke”
20 portion of the pumping cycle.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to figures 2 and 3; the hydraulically driven surface oil well pumping unit 12
25 of the present invention comprises a base portion 14, including a hydraulic power unit (not shown) and a mast portion 16 comprising a pair of single acting hydraulic cylinders 18 and a pair of double acting hydraulic cylinders 20. Figure 2 shows the hydraulic cylinders 18, 20 of the hydraulically driven oil field pumping unit 12 fully extended, and figure 3 shows the mast portion 16 separated from the rest of the oilfield pumping unit 12 of figure 2 with
30 the hydraulic cylinders 18, 20 fully retracted. The new oil well pumping unit 12 of the present invention is useful in reciprocating a “load” in the wellbore; particularly a load which is substantially higher as the load is being raised, than when the load is being lowered – as is typically the case when pumping oil in an oil well.

The cap ends 22a and 22b of the hydraulic cylinders 18, 20 are shown mounted to a common rigid base plate 24. The rod ends 26a 26b of the hydraulic cylinders 18, 20 are shown mounted to a common rigid end plate 28. It is anticipated that in operation the hydraulic cylinders 18, 20 will typically oriented with their cap ends 22a and 22b secured to the base plate 24, but it is also possible to mount them such that the cap ends 22a and 22b are mounted to the end plate 28, and use tension members to 'suspend' the load. The lifting mechanism is then suspended in a framework (not shown) using an intermediate support structure. It is preferred, however, to mount the cylinders 18, 20 with the cap ends 22a and 22b secured to the base plate 24 as shown, as this allows the forces from the 'load' to pass in compression directly from the cap ends 22a and 22b to the base plate 24. A frame with sufficient strength - or a separate base - may be needed to support the mast.

Referring now to figure 4, the hydraulic schematic 40 of the hydraulic power unit (shown generally as 30) of the hydraulically driven oil field pumping unit 12 is shown in figure 4 and is typical for pressure compensated power units. The hydraulic power unit 30 typically comprises but is not limited to one or more pumps 42, 44 powered by one or more engine 46 (or alternatively, motors). Hydraulic oil contained in a reservoir 48 is pumped into a control valve 50 which may be a proportional-volume controlled pressure balanced valve as illustrated, or may be a solenoid valve that is essentially open or closed.

The valve 50 is configured to reversibly provide pressurized hydraulic fluid to either of line 52a or 52b with the other line being the return. The operation of this valve 50 controls the extension and retraction of the hydraulic cylinders 18, 20. This hydraulic configuration may be comprised of, but not limited to a closed loop, solenoid operated hydraulic pumping unit.

The mast 16 lifting section comprises a pair of single acting hydraulic cylinders 18, and a pair of double acting hydraulic cylinders 20. As shown in Figs. 5 and 6, the cylinders 18, 20 are mechanically mounted on common end plates 24, 28 such that they all must extend and retract simultaneously.

The cap ends 54, 56 of the double acting cylinders 20 are 'closed-coupled' to one or more hydraulic accumulators 58, 60 so that in normal operation all the flow into and out of the cap ends 54, 56 of the cylinders flows into or out of the hydraulic accumulators 58, 60.

The accumulators 58, 60 are pre-charged with an inert gas to a pressure depending upon the weight of the load such that when the double acting cylinders 20 are fully extended they are able to hold a high percentage of the lifting load.

5 As illustrated in Figure 5, during the “up” stroke, pressurized fluid from the hydraulic power unit 30 is applied only to the cap ends 66, 68 of the single acting cylinders 18 through line 52a, causing all four of the cylinders 18, 20 to extend. The pair of single acting hydraulic cylinders 18 can only be powered in the extended direction.

10 The pressure required to operate the single acting cylinders 18 will steadily increase as the cylinders continue to extend because the load capability of the double acting cylinders 20 decreases as pressure drops in the accumulators 58, 60 as they empty their hydraulic fluid. The hydraulic pressure required to move the load is typically higher than the pressure required to ‘hold’ the load. So, even at the end of their strokes, the reduced pressure
15 available from the accumulators 58, 60 maybe adequate to keep the cylinders firmly and fully extended as the cycle reverses and the cylinders 18, 20 begin to retract. This ‘overcharging’ of the accumulators solves a known problem in the prior art hydraulic lift pumps, which have been known to ‘drop’ occasionally as the cylinders reverse and begin to retract. ‘Drops’ like this, if repeated frequently, may cause fatigue, and perhaps even
20 failure within the members comprising the “load”.

As illustrated in Figure 6, during the ‘down’ stroke, the pressurized fluid from the hydraulic power unit 30 is applied only to the ‘rod’ ends 62, 64 of the double acting hydraulic cylinders 20 through line 52b. The combination of the weight of the load and
25 this hydraulic pressure on the top end of the cylinder causes the cylinders to retract. This in turn forces the hydraulic fluid on the cap ends 54, 56 of the double acting cylinders 20 back into the accumulators – and therefore recharging them, and completing the cycle.

In operation, the pre-charge pressures of the accumulators 58, 60 are ‘tuned’ so that in
30 conjunction with the weight of the load, the horsepower to raise and lower the load is substantially the same throughout the entire extend/retract cycle. This allows optimal sizing of the engine(s) 46 (or motors) driving the hydraulic pumps 42, 44; and may improve the overall useful lifetime of the oil well pumping unit 12, by reducing the accompanying cyclic fatigue. In some selected embodiments the lowering load may be set

within a range of about 60% to 95% of the raising load. In other selected embodiments it may be preferable to limit the lowering load to no lower than about 70% of the raising load. In still other selected embodiments, it may be desirable to maintain the lowering load in a range of 75% to 85% of the raising load.

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In some selected embodiments, this ratio of lowering load to raising load may be further adjusted by varying the pre-charge pressures among the accumulators 58, 60. In this embodiment three or four or more than four accumulations with varying pre-charge pressures may be useful.

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In other selected embodiments the ratio of lowering load to raising load may be adjusted by varying the distribution of swept volumes among the accumulators. In still other selected embodiments the ratio of lowering load to raising load may be adjusted by using different volume capacities among the accumulators.

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For those instances where precise tuning and 'leveling' of the horsepower is important, accumulators 58, 60 may be arranged with both different pre-charge pressures, and with different volume capacities, which may 'tuning' even more precise.

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Although the system described herein is disclosed as having two single acting hydraulic cylinders 18 and two double acting hydraulic cylinders 20, it would be apparent to those skilled in the art that the system only requires one or more of each of the single 18 and/or double 20 acting cylinders to operate in the manner described. The second cylinders 18, 20 allow for a more compact 'footprint' and provides for greater mechanical stability to the structure.

25

Whereas the present invention has been described in particular relation to the drawings attached hereto, it should be understood that other and further modifications apart from those shown or suggested herein, may be made within the scope and spirit of the present invention.

30

CLAIMS

What is claimed is:

- 5 1. A vertically orientated reciprocating oil well pumping unit comprising:
at least one double acting hydraulic cylinder, mechanically coupled to at least one
single acting hydraulic cylinder such that they extend and retract simultaneously to operate
the pumping unit,
the cap end of the double acting hydraulic cylinder in close-coupled fluid
10 communication with a fluid end of a hydraulic accumulator, the accumulator having a
precharge pressure at least exceeding a loading pressure in the cap end of the hydraulic
cylinder when it is fully extended in use and under load;
a hydraulic control valve having a first inlet/outlet port in fluid communication with
the cap end of the single acting hydraulic cylinder and the valve having a second
15 outlet/inlet port in fluid communication with the rod end of the double acting hydraulic
cylinder, whereby,
when the hydraulic control valve is operated to retract the cylinders, hydraulic
pressure is applied to the rod end of the double acting hydraulic cylinder forcing it and the
coupled single acting hydraulic cylinder to retract simultaneously, thereby causing the fluid
20 from the cap end of the double acting cylinder to flow back into the accumulator, and,
causing the fluid from the cap end of the single acting cylinder to flow back through
the return port of the hydraulic control valve into a hydraulic reservoir.
- 25 2. The vertically orientated surface oil well pumping unit of claim 1 wherein the four-way
hydraulic control valve is pressure compensated.
3. The vertically orientated surface oil well pumping unit of claim 1 wherein the pumping
unit further comprises a pressure compensated hydraulic pump.
- 30 4. The vertically orientated surface oil well pumping unit of claim 1 wherein the cap end
of the double acting hydraulic cylinder and cap end the single acting hydraulic cylinder are
mechanically mounted to a common rigid base plate.

5. The vertically orientated surface oil well pumping unit of claim 1 wherein the rod ends of the hydraulic cylinders are mounted to a common rigid end plate.
6. The vertically orientated surface oil well pumping unit of claim 1 wherein the
5 accumulators are precharged to a pressure sufficient to hold the load in place with the pump not operating.
7. The vertically orientated surface oil well pumping unit of claim 1 wherein when the
10 four-way type hydraulic control valve is operated to extend the cylinders, hydraulic pressure is applied to the cap end of the double acting hydraulic cylinder forcing it and the coupled single acting hydraulic cylinder to extend simultaneously, thereby allowing
15 pressurized fluid from the accumulators to flow into cap end of the single acting cylinder thereby assisting in extending the cylinders.
8. A vertically orientated reciprocating oil well pumping unit comprising:
at least one double acting hydraulic cylinder, mechanically coupled to at least one
single acting hydraulic cylinder such that they extend and retract simultaneously to operate
the pumping unit,
a cap end of the double acting hydraulic cylinder in close-coupled fluid
20 communication with a fluid end of a hydraulic accumulator, the accumulator having a precharge pressure at least exceeding a loading pressure in the cap end of the hydraulic cylinder when it is fully extended in use and under load;
whereby, in operation under load, the power required to extend the reciprocating oil
well pumping unit is approximately equal to the power required to retract the reciprocating
25 oil well pumping unit.
9. The vertically orientated surface oil well pumping unit of claim 8 wherein the four-way type hydraulic control valve is pressure compensated.
- 30 10. The vertically orientated surface oil well pumping unit of claim 9 wherein the pumping unit further comprises a pressure compensated hydraulic pump.

11. The vertically orientated surface oil well pumping unit of claim 10 wherein the cap end of the double acting hydraulic cylinder and cap end the single acting hydraulic cylinder are mechanically mounted to a common rigid base plate.
- 5 12. The vertically orientated surface oil well pumping unit of claim 11 wherein the rod ends of the hydraulic cylinders are mounted to a common rigid end plate.
13. The vertically orientated surface oil well pumping unit of claim 12 wherein the accumulators are precharged to a pressure sufficient to hold the load in place with the
10 pump not operating.
14. The vertically orientated surface oil well pumping unit of claim 13 wherein when the four-way type hydraulic control valve is operated to extend the cylinders, hydraulic pressure is applied to the cap end of the double acting hydraulic cylinder forcing it and the
15 coupled single acting hydraulic cylinder to extend simultaneously, thereby allowing pressurized fluid from the accumulators to flow into cap end of the single acting cylinder thereby assisting in extending the cylinders.
15. The vertically orientated surface oil well pumping unit of claim 8 wherein a lowering
20 load is 60% to 90% of a raising the load.
16. The vertically orientated surface oil well pumping unit of claim 15 wherein the lowering load is 66% of the raising the load.
- 25 17. The vertically orientated surface oil well pumping unit of claim 15 wherein the lowering load is at least 75 to 86% of the raising the load.
18. The vertically orientated surface oil well pumping unit of claim 12 wherein the accumulators are precharged to different pressures, that are nonetheless sufficient to hold
30 the load in place with the pump not operating.
19. A hydraulic control valve having a first inlet/outlet port in fluid communication with the cap end of a single acting hydraulic cylinder and the valve having a second outlet/inlet

port in fluid communication with the rod end of a double acting hydraulic cylinder to operate a reciprocating pump, whereby, fluid pressure from a hydraulic pumping unit provides hydraulic fluid under pressure such that when the four-way type hydraulic control valve is operated to retract the cylinders, hydraulic pressure is applied to the rod end of the double acting hydraulic cylinder forcing it and the coupled single acting hydraulic cylinder to retract simultaneously, thereby causing the fluid from the cap end of the double acting cylinder to flow back into the accumulator, and the fluid from the cap end of the single acting cylinder to flow back through the return port of the four-way hydraulic control valve into a hydraulic reservoir.

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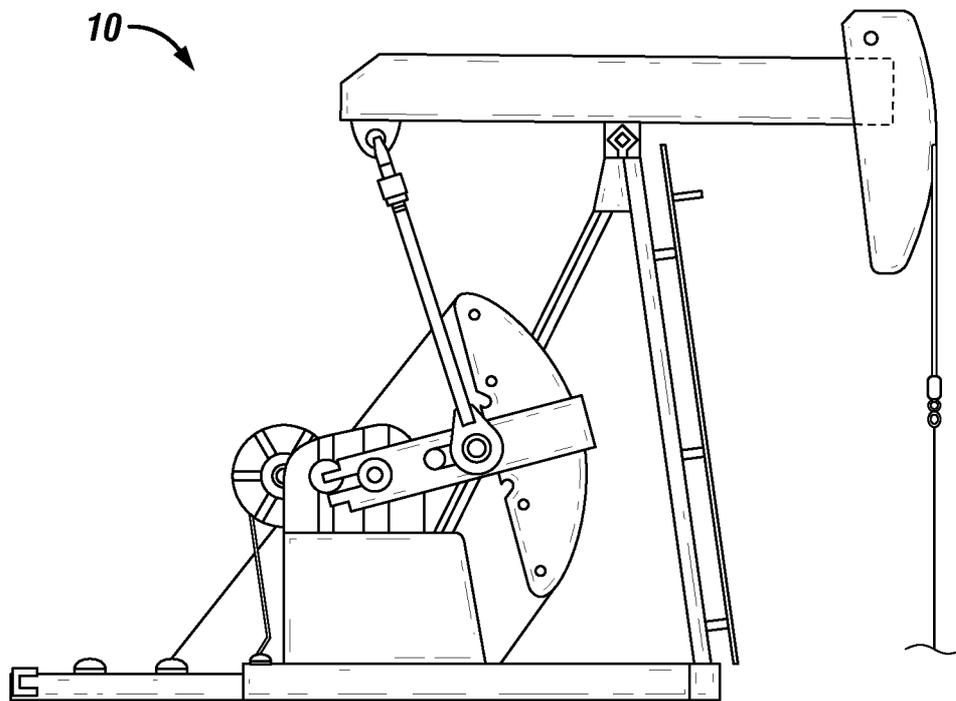


FIG. 1
(Prior Art)

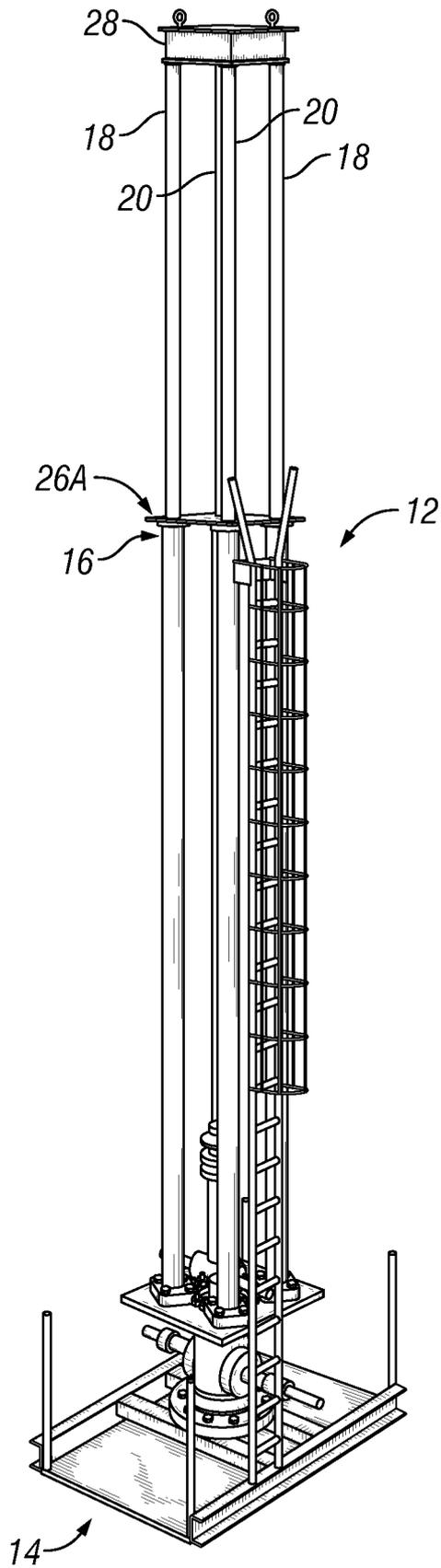


FIG. 2

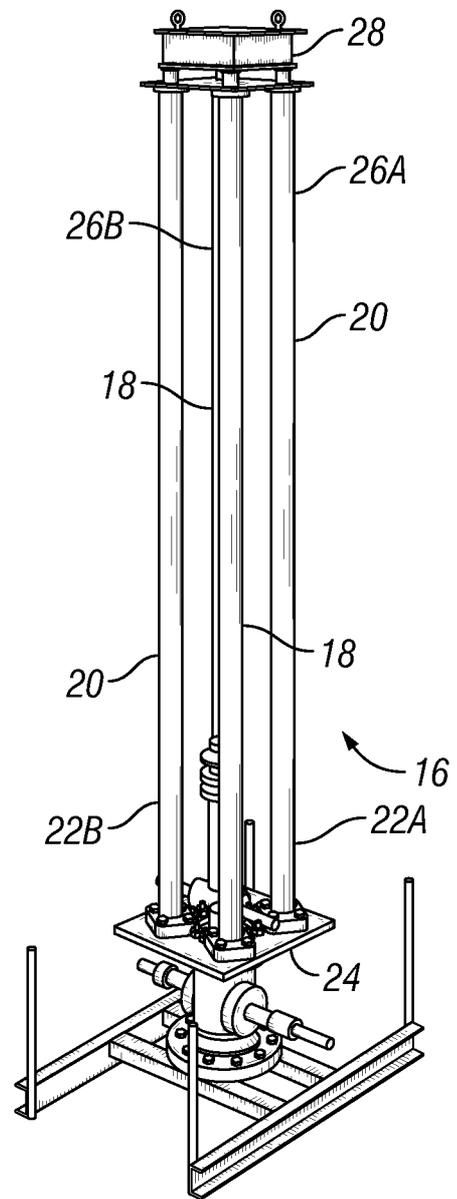


FIG. 3

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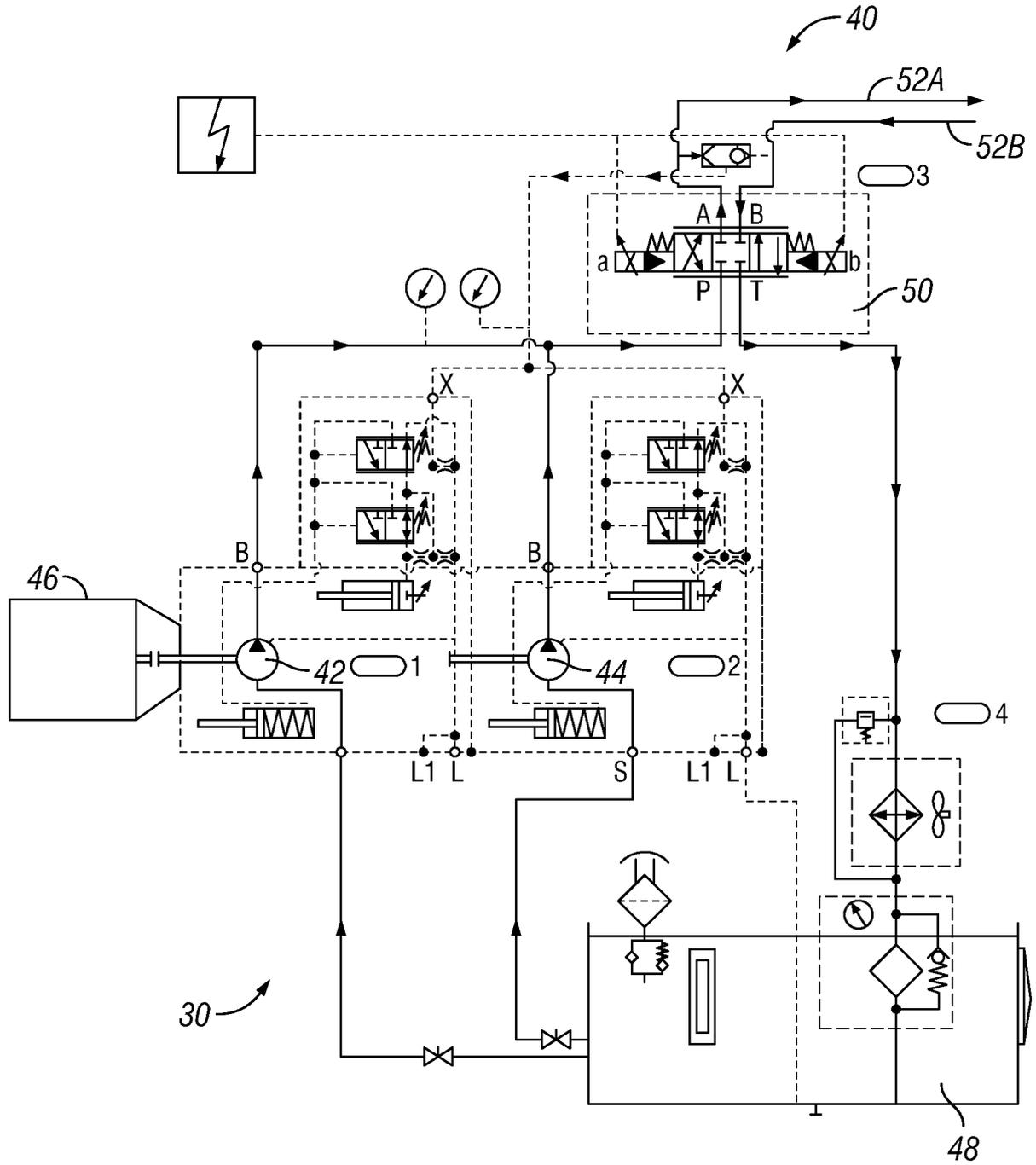


FIG. 4

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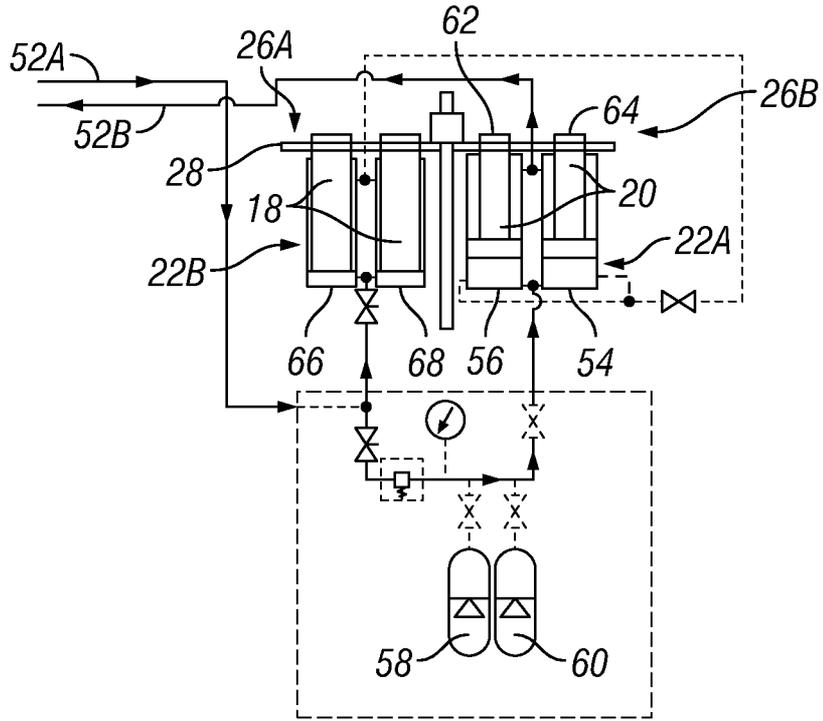


FIG. 5

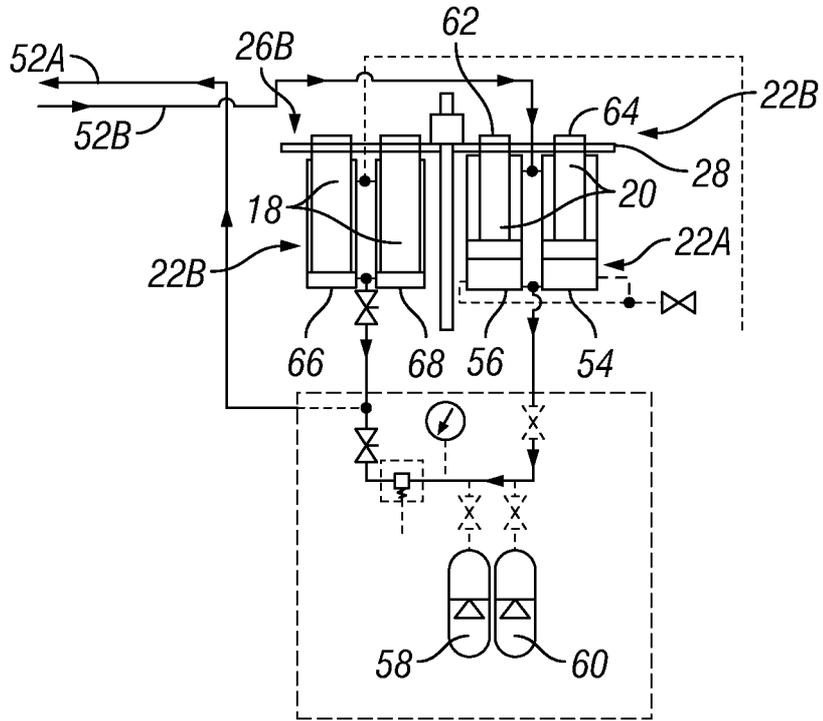


FIG. 6