Dec. 27, 1938. G. S. BAYS 2,141,703

HYDRAULIC-PNEUMATIC PUMPING SYSTEM

Filed Nov. 4, 1937 2 Sheets-Sheet 1

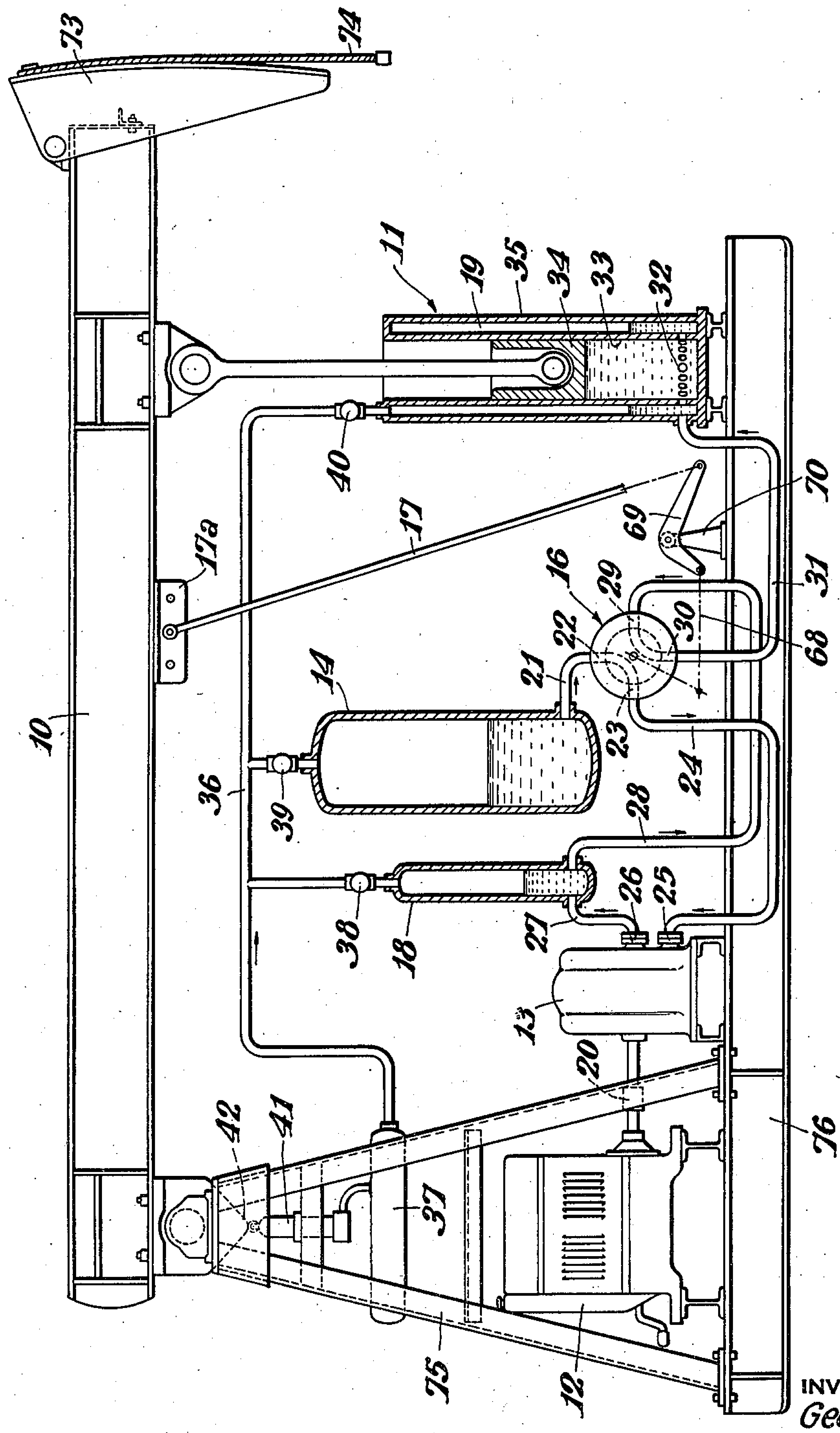

Fig. 1

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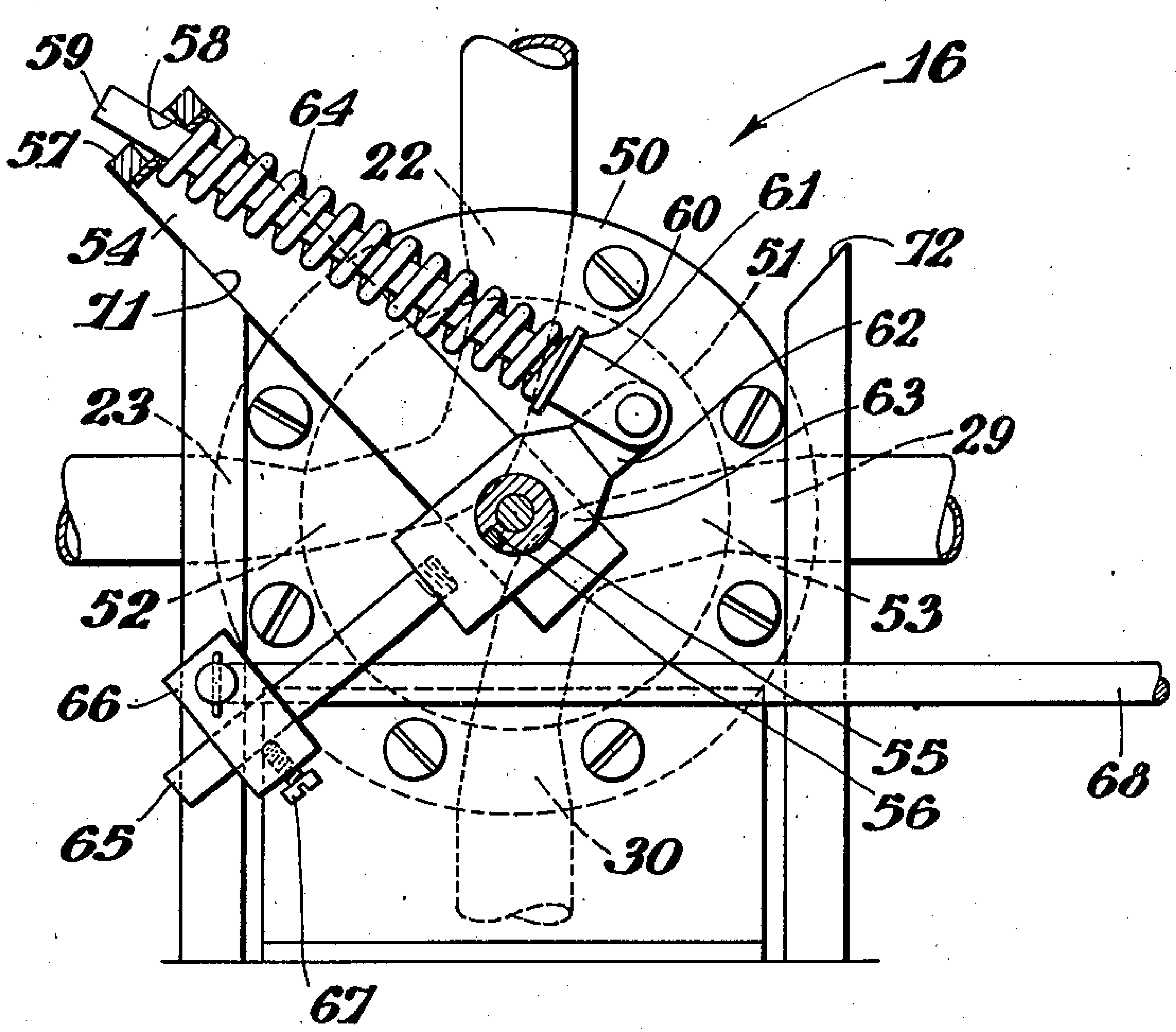
Fig. 2



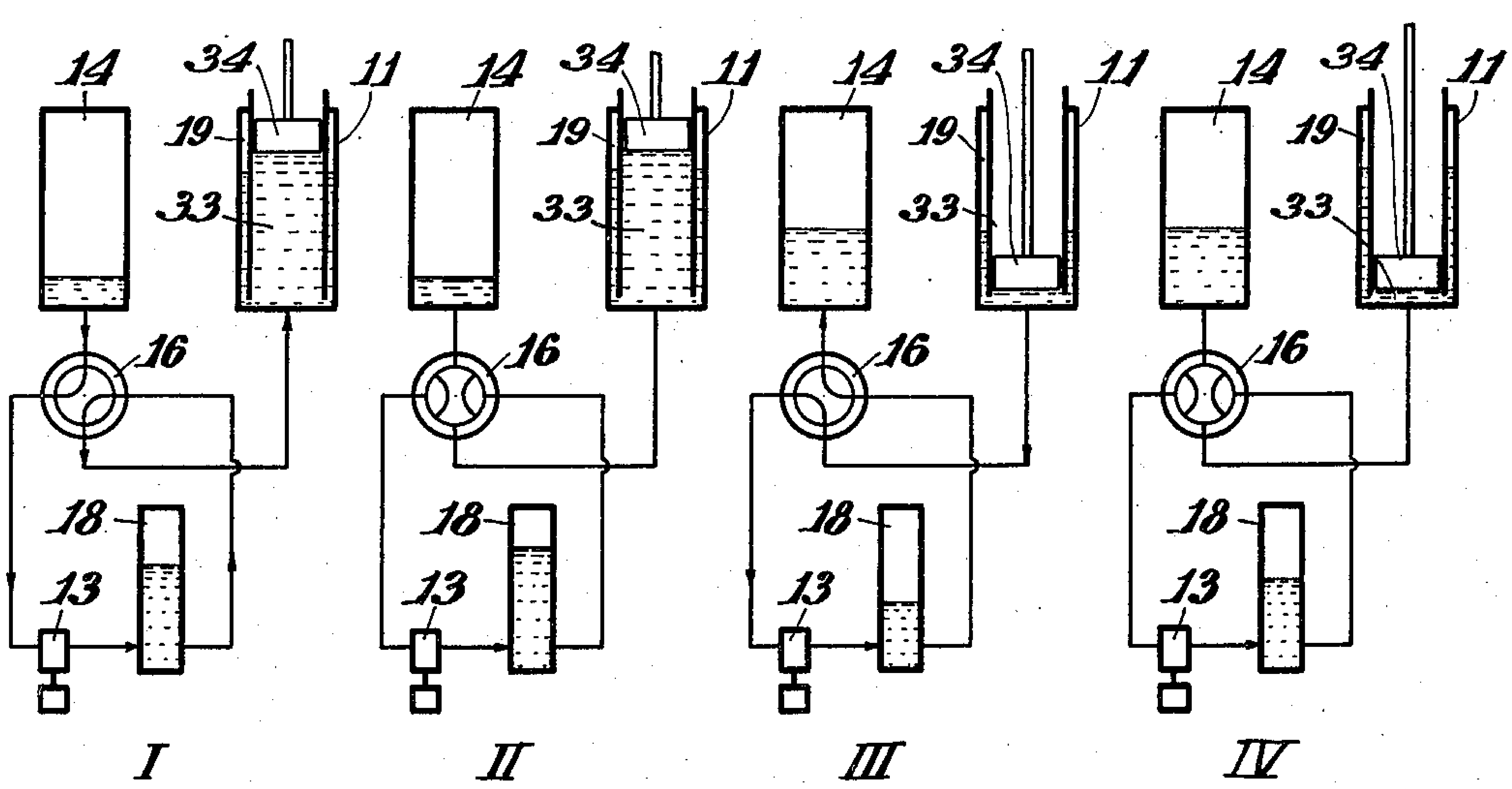


Fig. 3

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HYDRAULIC-PNEUMATIC PUMPING SYSTEM

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6 Claims. (Cl. 60—52)

This invention relates to hydraulic-pneumatic power systems and particularly to hydraulic-pneumatic pump counter-balancing and operating systems for pumping wells such as oil wells.

The problem of furnishing a satisfactory supply of fluid pressure for driving a reciprocating piston type of motor has for a long time presented great difficulty. One of the principal reasons for this difficulty resides in the fact that this type of motor requires a periodic supply of fluid pressure which in the absence of some special provision results in a variable load on the prime mover. This variable load on the prime mover—particularly in the case where an internal combustion engine is employed—results in a very inefficient and unsatisfactory operation.

This condition is found to be particularly acute in the case of an internal combustion engine operating a fluid pump which in turn drives a reciprocating fluid motor for raising and lowering the walking beam of an oil well pump, the outer end of which beam reciprocates the polish rod and pump rods in a well-known manner. When the motor is lifting the walking beam to raise the pump rods, maximum power is being exacted from the internal combustion engine, while on the other hand during lowering of the pump rods no power output is required of the internal combustion engine. I am aware that various solutions to this problem have been proposed heretofore, such as the provision of a reciprocating or rotary counter-balance for the walking beam, as well as pneumatic counter-balances. However, insofar as I am aware, none of these proposed solutions has proven entirely satisfactory. In the case of the rotary or reciprocating counter-balances, particuarly, experience has shown that the inertia forces involved are so great upon reversal of the pump rods as to result in numerous breakages thereof and consequent expensive shutdowns for repair.

One object of my invention is to provide well pumping equipment which will conserve energy to the maximum possible extent. Another object is to avoid peak loads on prime movers used in well pumping. Another object is to provide equipment which will minimize shock loads on the pump rods.

It is a more detailed object of the present invention to supply a novel combination of prime mover, pump, reciprocating motor, and control means between the pump outlet and the motor to effect a more complete conservation of the output of the prime mover than has heretofore been possible by means of known equipment. Still more specifically it is an object of this invention to so control the fluid delivered by the pump to the reciprocating motor that a substantially uniform loading of the prime mover throughout the cycle of operation is effected, thus making possible the use of an internal combustion engine in the capacity of the prime mover with higher efficiency than possible with heretofore known equipment.

A further object of this invention is to provide in combination with a reciprocating piston type of motor, which is subject to sudden inertia loads, an arrangement of equipment for absorbing the shock of such loads. More specifically it is an object to provide this arrangement in combination with the pump rods of an oil well pump for absorbing the inertia forces incident to the operation thereof.

The above and other objects, advantages and uses of my invention will become more apparent from a reading of the following specification taken in connection with the appended drawings which form a part thereof and wherein:

Figure 1 is a diagrammatic elevation partially in section illustrating schematically the relationship of the various elements of equipment in a preferred embodiment of my invention;

Figure 2 is a front elevation of my improved valve and snap-operating mechanism therefor;

Figure 3, Parts I, II, III and IV, are diagrammatic views illustrating the successive relationships existing in the apparatus during the cycle of operation.

Referring in greater detail to Figure 1, I show my improved arrangement of power apparatus in its particular application to the operation of the walking beam of an oil pump. Walking beam 10 is raised and lowered by a reciprocating piston type of fluid motor 11. This motor is supplied with driving fluid by means of a novel arrangement of prime mover 12, fluid pump 13, and control means for the fluid delivered by pump 13 to the motor 11. This novel arrangement of control means consists essentially of an energy-storing chamber of counterbalancing chamber 14 maintained under pressure and connected to the input of the pump during the beam-lifting operation to assist the pump in effecting the raising of the piston of the motor 11 and connected to the output of the pump during the lowering operation for storing energy.

In other words, the pump 13 pumps liquid from the energy-storing chamber 14 to the motor during the raising of the motor piston 34 and pumps liquid from the motor to the energy-storing chamber during the lowering of the motor piston, thus taking advantage of the potential and kinetic energy of the falling rods in conserving energy for subsequent use in raising the motor piston, walking beam and pump rods.

As the means for effecting the particular change in connections required, I have provided a special arrangement of two-way rotary plug valve 16 and means responsive to the movement of the motor piston into its limiting positions for effecting the operation of this valve including connecting rod 17 and associated devices.

More specifically I have provided in addition to energy-storing chamber 14 a surge chamber 18 directly connected with the discharge of pump 13 which serves the function of making the pressure changes more gradual and providing a cushioning effect, particularly while the reversal of connections (later to be described) is taking place.

Also I have provided a shock-absorbing chamber 19 in connection with the lifting motor 11 to absorb the sudden inertia forces to which the pumping equipment is subjected, particularly those inertia forces incident to the reversal of the equipment.

The prime mover 12 is preferably a plural cylinder internal combustion engine connected by coupling 20 to the drive shaft of the rotary pump 13. The engine 12 is furnished with the usual supply of fuel and control devices, the details of which need not be described.

In the relative positions of elements indicated in Figure 1 with the walking beam 10 in its intermediate position, rotary plug valve 16 connects energy-storing chamber 14 through conduit 21, valve port 22, valve port 23, conduit 24, pump inlet 25, pump outlet 26, conduit 27, surge chamber 18, conduit 28, plug valve port 29, plug valve port 30, conduit 31, lower portion of shock absorber chamber 19 and ports 32 with inner cylinder 33 to raise piston 34, walking beam 10 and the pump rods (not shown).

Referring now in greater detail to certain of the key elements, it is to be noted that surge chamber 18 is a closed pressure chamber formed with walls of suitable thickness and provided with a supply of pumping liquid such for example as oil or water above the level of which is maintained an air or other gas space under suitable pressure. The level of the liquid in surge chamber 18, as well as the pressure in the air space therein, will be varied during the cycle of operations, as will more clearly appear as the description proceeds. The energy-storing chamber 14 is likewise supplied with driving liquid above which there is maintained an air space under pressure, the volume and pressure of which will also be varied during the cycle of operations, as will more particularly appear as the description proceeds.

Motor 11 is composed of an inner cylinder 33 open at the top and closed at the bottom (except for peripherally disposed ports 32), a reciprocating piston 34 arranged for vertical movement therein, and an outer cylinder 35 spaced from inner cylinder 33 and coaxially disposed in relation thereto. This outer cylinder forms with the inner cylinder an annular shock-absorbing chamber 19. Shock-absorbing chamber 19 is supplied with driving liquid in the lower portion thereof and has an air space above the level of the driving liquid which is maintained under pressure.

Each of the chambers 14, 18 and 19 is supplied with an initial air or other gaseous pressure through conduit 36 from make-up receiver 37 under the control of one-way valves 38, 39 and 40 respectively. These valves may be manually operated but preferably operate automatically when the pressure differential drops below a predetermined value. Make-up receiver 37 is originally charged as by means of a pump (not shown) operated from prime mover 12. After the operation of the system is begun, make-up receiver 37 has its pressure maintained by means of make-up pump 41 operated by cam plate 42 attached to the pivoted end of walking beam 10. In the absence of pre-charging of chambers 14, 18 and 19, make-up pump 41 may be utilized to charge the system by operating the equipment unloaded.

Referring more specifically to rotary plug valve 16 (see Figure 2) it will be seen that this valve is composed essentially of a cylindrical housing 50 provided with ports 22, 23, 29 and 30 radially disposed substantially ninety degrees apart about the periphery of the housing. A rotary plug core 51 is provided with two separate passages 52 and 53 therethrough, the ends of which are arranged to cooperate alternately with the valve ports when the plug is rotated through ninety degrees, as indicated on the drawings.

A special arrangement is provided for effecting the snap operation of rotary plug 51 from one of its positions to another in accordance with the movement of the motor piston 34 to its limiting positions. This arrangement consists essentially of a valve plug operating arm 54 keyed to the valve plug shaft 55 by set screw 56. The outer end 57 of valve plug operating arm 54 is bent forward at right angles and formed with a circular opening 58 which receives a pin 59 for reciprocating movement therein. The opposite end of pin 59 is provided with a flange 60 and a yoke 61 for pivotal connection with ear 62 of a hub 63 rotatably mounted on plug shaft 55. Embracing pin 59 and interposed between flange 60 and the under face of end 57 of valve-operating arm 54 is a compression spring 64 which serves a key function in the operation of the snap mechanism as will hereinafter appear. A second pin 65 extends from hub 63 and is attached thereto by a threaded connection. Mounted on pin 65 for adjustment relative thereto is collar 66 having set screw 67 for adjusting the same on pin 65. Pivotally connected to collar 66 is connecting link 68, the opposite end of which is pivotally associated with the end of a bell crank 69 (see Figure 1) mounted on bracket 70. Connecting rod 17 joins the opposite end of bell crank 69 with adjustable plate connector 17*a* attached to the under side of walking beam 10.

It will be seen that as the walking beam approaches its limit of movement in the upward direction connecting rod 17 acting through bell crank 69, link 68, pin 65, and hub 63 causes a counterclockwise movement of hub 63 and compresses spring 64 to a point where the longitudinal axis of hub 63 coincides with and moves slightly beyond the axis of the pin 59, whereupon spring 64 becomes effective through valve-operating arm 54 to snap this arm through ninety degrees from stop 71 into contact with stop 72, thus rotating the rotary plug 51 to reverse the connections through the valve. Similarly this operation is reversed upon the movement of the walking beam to its other extreme position.

Referring now to the diagrammatic showing in Figure 3, Parts I, II, III and IV, the essential action of my hydraulic-pneumatic pump counterbalancing and operating system during one cycle of the pumping stroke will be given.

Figure 3, Part I, indicates the various elements in the positions they occupy with the motor piston 34 in its elevated position at the end of the upstroke. The pump takes suction on chamber 14 and discharges through chamber 18 into cylinder 33 or chamber 19 surrounding it. Assuming a working pressure of 300 lbs. per sq. in. in cylinder 33 for a given size of equipment, the pressure in chamber 14 may suitably be given an initial value of 237 lbs. per sq. in. at the beginning of the upstroke and will drop to about 213 lbs. per sq. in. at the end of the upstroke with an average pressure in the air space therein of about 225 lbs. per sq. in. The average pressure differential across pump 13 under these conditions is, of course, 75 lbs. per sq. in. Approximately this same average pressure differential prevails on the upstroke and thus the prime mover operates under substantially constant load.

As shown in Figure 3, Part II, the valve reverses when the piston reaches some point near the top of its stroke and the valve is temporarily in a closed or neutral position. During this brief interval the liquid level in chamber 18 fluctuates slightly and it serves to take up the shock occasioned by the reversal of the valve.

The downstroke then commences as shown in Figure 3, Part III. Liquid is withdrawn from cylinder 33 and chamber 19 and is discharged through chamber 18 into chamber 14. During this part of the cycle the working head of the pump is the difference between the pressure exerted on cylinder 33 and chamber 19 by the weight of the falling rods and the pressure in chamber 14 due to the compression of air or other gas above the liquid. The weight of the falling rods is assumed to correspond to a pressure of 150 lbs. per sq. in. or half the working pressure in the motor cylinder. With the assumed conditions the pressure in chamber 14 increases from 213 lbs. per sq. in. to 237 lbs. per sq. in. during this part of the cycle and the average pressure differential across the pump is 75 lbs. per sq. in. as on the upstroke.

Figure 3, Part IV, shows the valve in neutral position at the bottom of the downstroke. Again surge chamber 18 absorbs the surge incident to the valve reversal operation. The position of Figure 3, Part I, is then restored, the working pressure builds up to 300 lbs. per sq. in. in cylinder 33, the air spaces in chambers 18 and 19, particularly the latter, serving to cushion the shock of the increasing pressure, and the cycle is repeated.

The minimum volume of the counterbalancing chamber 14 relative to that of the pumping cylinder 33 is about 12.5 to 1. Similarly, the minimum volume of the surge chamber 18 relative to that of the pumping cylinder 33 is about 2.2 to 1 and the minimum value of the shock-absorbing chamber 19 relative to that of the pumping cylinder 33 is about 0.2 to 1.

It will be apparent that the pumping system of my invention has numerous important advantages. Prominent among these are:

1. The conservation of energy.

2. A lower peak load, making possible a smaller prime mover, either motor or engine. This is accomplished through the more uniform loading of the power unit throughout the cycle. The volume chambers can be so designed that the work of the power unit on the downstroke is practically the same as on the upstroke. This is a special advantage in making possible smoother operation of internal combustion engines, leading to a longer life. Practically all present equipment calls for maximum loads on the power unit during the upstroke, and little load during the downstroke.

3. The rods are never subject to the shock loads imposed on them by all mechanical pumping equipment now in use. The air in the annular space 19 cushions any impact and floats the rods virtually on air throughout their upstroke and downstroke. This last advantage is particularly beneficial to the rods, as their life is affected probably as much by the instantaneous loading imposed upon them by the use of the present type of mechanical equipment, as it is through the stress of carrying the uniform load of oil or other liquid being pumped.

While I have shown the shock absorbing chamber 19 as forming a part of motor 11, and prefer this modification as being the more efficient and satisfactory one, it is to be understood that my invention in this respect is broader than the specific structure disclosed. Basically I contemplate the provision of any equivalent shock-absorbing chamber interposed between valve port 30 and motor 11.

I have not gone into any great amount of detail in describing conventional portions of my equipment, but I contemplate the necessary additional equipment such as the curved head 73 mounted on the end of the walking beam 10, as well as cable 74 adapted to be connected to the polish rod of an oil well pump, Samson post 75 and mounting base 76, together with such other equipment as is necessary. The various chambers may suitably be insulated to render the compression and expansion of the air or other gas more nearly adiabatic. Pressure release valves can be installed to take care of emergencies such as reversing valve failures, etc.

While I have described my invention in connection with certain specific embodiments thereof, it is to be understood that I contemplate all equivalents and intend to be limited only as indicated by the appended claims which should be given a scope as broad as the prior art will permit.

I claim:

1. In combination in an hydraulic-pneumatic well pumping system, a prime mover, a liquid pump driven by said prime mover, a reciprocating piston type motor arranged to be driven by the liquid from said pump, an energy-storing chamber provided with a supply of said driving liquid and a gas space under pressure thereabove, means including a valve operable in response to the movement of the motor piston to retracted position effective to connect the input of said pump with said energy-storing chamber and the output of said pump with said motor to effect the operation of said piston, said means being further operable in response to the movement of said piston to its extended position to change said connections to connect the input of said pump with said motor and the output of said pump with said energy-storing chamber, and a shock absorber interposed between said motor and said valve, said shock absorber comprising a chamber having a liquid level therein above which there is provided an air space under pressure, said air space being effective to absorb the sudden inertia forces impressed upon said piston.

2. In combination in an hydraulic-pneumatic well pumping system, a prime mover, a liquid pump driven by said prime mover, a reciprocating piston type motor arranged to be driven by the liquid from said pump and including a piston and a cylinder, a shock absorbing chamber surrounding said cylinder, closed at the top and communicating with said cylinder beneath the lowermost position of said piston, said shock absorbing chamber being provided with a supply of said driving liquid and a gas space under pressure above said driving liquid, an energy-storing chamber provided with a supply of said driving liquid and a gas space under pressure thereabove, and means including a valve operable in response to the movement of said piston to retracted position effective to connect the input of said pump with said energy-storing chamber and the output of said pump with said shock absorbing chamber and through it with said motor to effect the operation of said piston, said means being further operable in response to the movement of said piston to its extended position to change said connections to connect the input of said pump with said shock absorbing chamber and through it with said motor and the output of said pump with said energy-storing chamber.

3. The combination of claim 2 wherein there is provided a hydraulic-pneumatic surge chamber interposed between the output of said pump and said valve.

4. In combination in an hydraulic-pneumatic well pumping system, a prime mover, a liquid pump driven by said prime mover, a reciprocating piston type motor arranged to be driven by the liquid from said pump, control means for controlling the liquid delivered by said pump to said motor whereby said prime mover can be driven at substantially constant load while said motor absorbs power periodically, said means comprising a surge chamber in constant communication with the discharge outlet of said pump, said surge chamber being provided with a supply of said driving liquid therein and an air space above said liquid under pressure, an energy-storing chamber, said energy-storing chamber being provided with a supply of driving liquid therein and an air space above said liquid under pressure, means including a valve operable in response to the movement of the piston of said motor to its retracted position to connect said surge chamber to said motor and said energy-storing chamber to the inlet of said pump, said means being further operable in response to the movement of said motor piston to its extended position to change said above-named connections to connect said surge chamber with said energy-storing chamber and said motor with the intake connection of said pump.

5. In combination in an hydraulic-pneumatic well-pumping system, a prime mover, a liquid pump driven by said prime mover, a reciprocating piston type motor arranged to be driven by the liquid from said pump and including a piston and a cylinder, an energy-storing chamber provided with a supply of said driving liquid under superimposed gas pressure, means including a valve operable in response to movement of said piston to retracted position to connect the input of said pump with said energy-storing chamber and the output of said pump with said motor to effect the operation of said piston, said means being further operable in response to the movement of said piston to its extended position to connect the input of said pump with said motor and the output of said pump with said energy-storing chamber, a surge chamber provided with a supply of said driving liquid under superimposed gas pressure in constant communication with the output of said pump, a gas compressor actuated by said motor, and means for supplying gas from said compressor to said energy-storing chamber and said surge chamber to maintain said gas pressure in said chambers.

6. The combination of claim 5 wherein there is provided a shock-absorbing chamber having a supply of said driving liquid under superimposed gas pressure in constant communication with said motor, and means for supplying gas from said compressor to said shock-absorbing chamber to maintain said gas pressure in said chamber.

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