

Jan. 31, 1939.

R. P. MILLER

2,145,402

PUMP

Filed Oct. 26, 1935

3 Sheets-Sheet 1

Fig. 1.

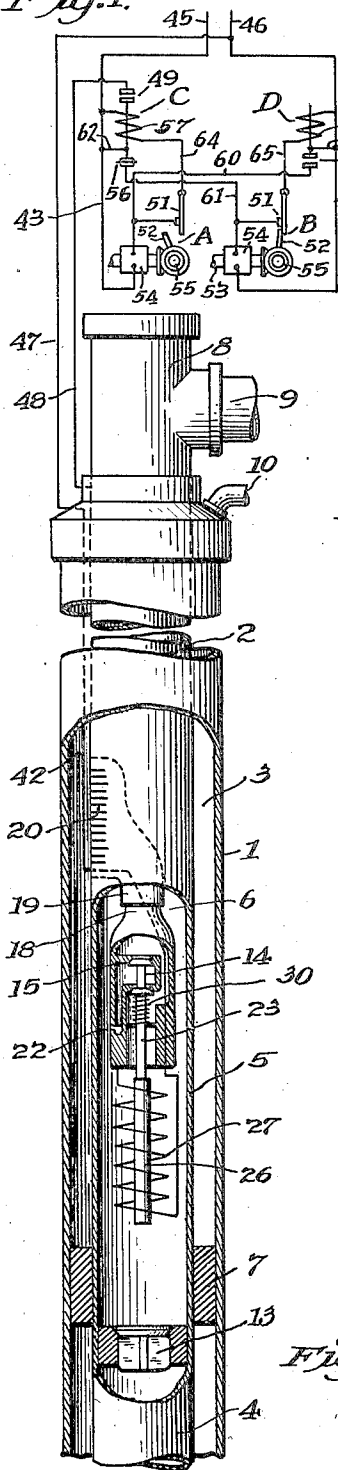


Fig. 2.

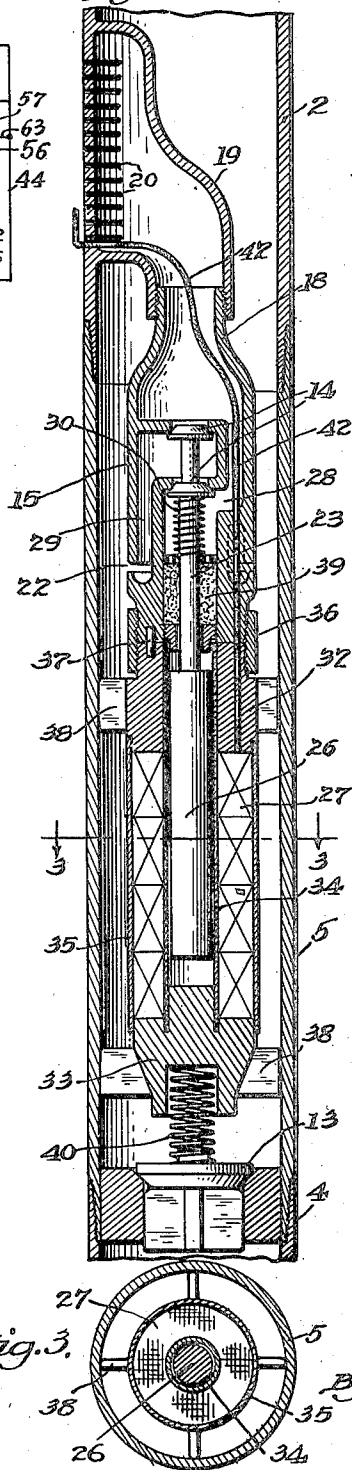


Fig. 4.

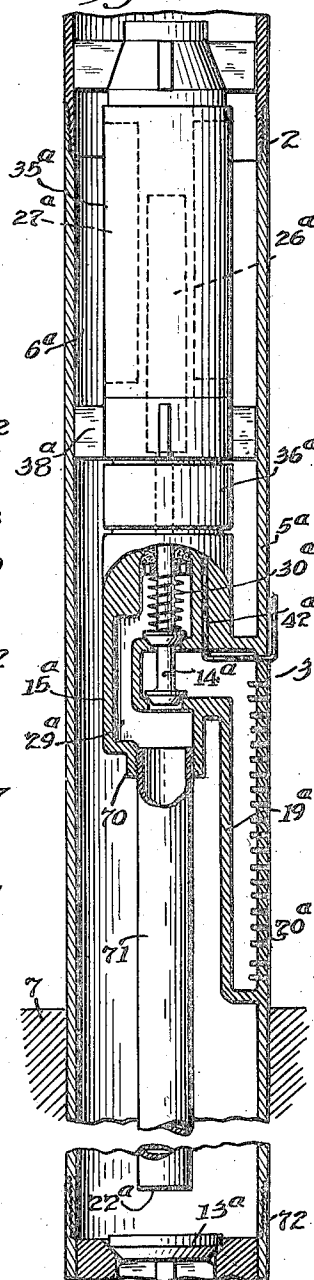
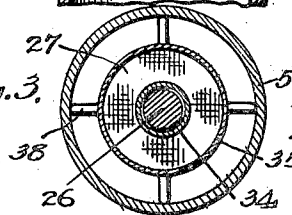


Fig. 3.



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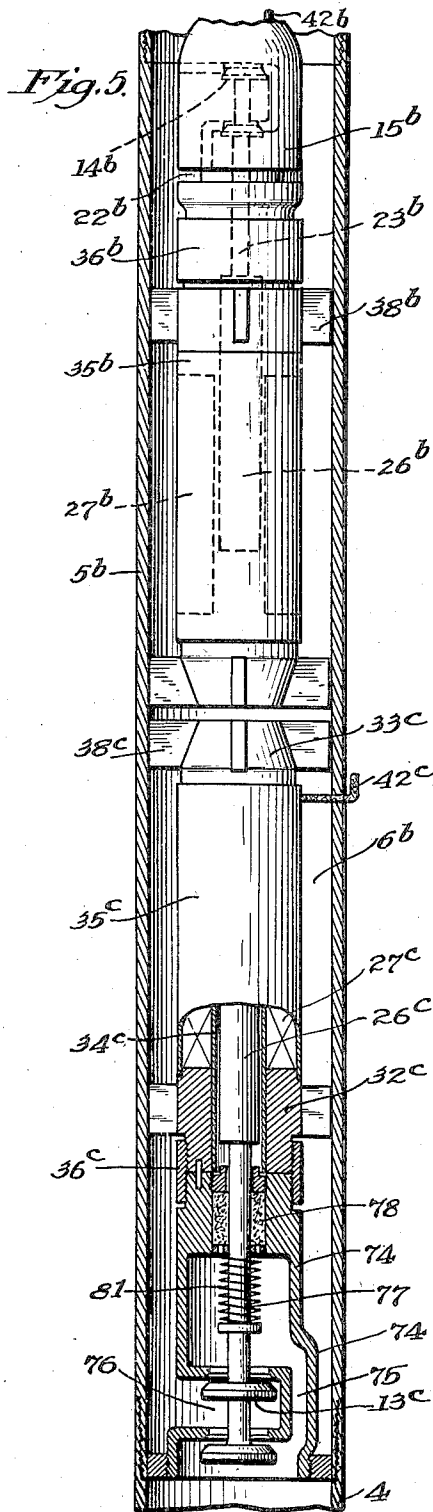
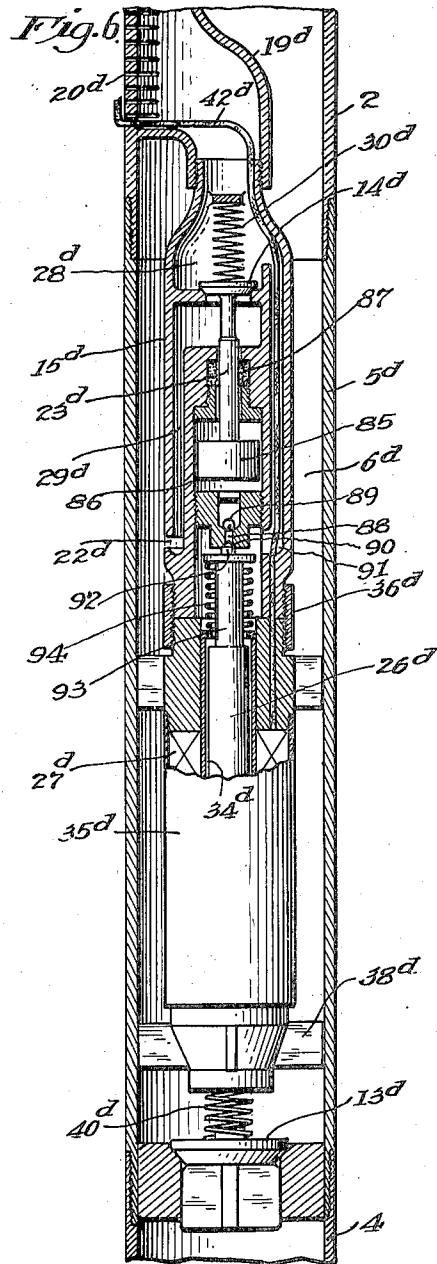
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3 Sheets-Sheet 2



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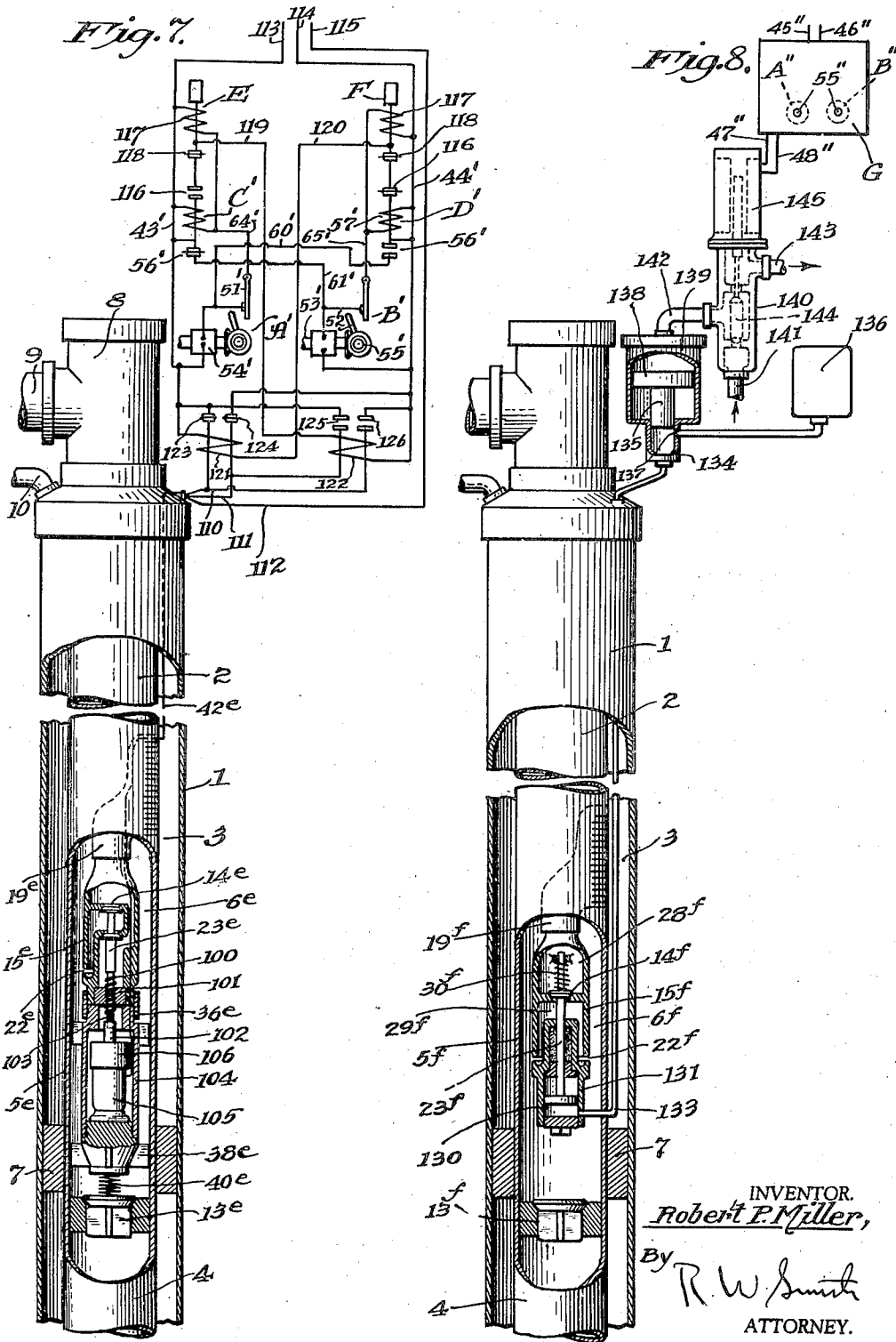
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3 Sheets-Sheet 3



UNITED STATES PATENT OFFICE

2,145,402

PUMP

Robert P. Miller, San Gabriel, Calif.

Application October 26, 1935, Serial No. 46,913

26 Claims. (Cl. 103—241)

This invention relates to that type of fluid pressure displacement pump wherein a fluid which is to be pumped, hereinafter sometimes referred to as product in fluid, and a cooperating displacing pressure fluid are alternately admitted to a conduit, so that at each cycle of operation a volume of the fluid which is to be pumped is forced through the conduit by a fluid piston of the pressure fluid; and it is the object of the invention to positively control this alternate admission of fluids, independently of their pressure differential.

More particularly the invention relates to that type of pump wherein a valve, generally designated a foot valve, controls admission to a conduit of the fluid to be pumped, and a valve, generally designated a head valve, controls admission of pressure fluid to the conduit. When the foot valve is open the head valve is closed, thereby shutting off the pressure fluid from the conduit and permitting the fluid which is to be pumped, to enter the conduit to its static or working level. This is the filling period. The foot valve is then closed and the head valve is opened. Pressure fluid supplied to the conduit via the open head valve thus displaces the volume of fluid to be pumped, which has been trapped in the conduit above the closed foot valve; and this trapped volume of fluid is thus forced through the conduit. This is the discharge period. The head valve is then again closed and the foot valve opened, so that the cycle of operation is repeated.

Heretofore there have been pumps of this type wherein the head and foot valves have been connected for dependent operation by pressure differential between the displacing fluid and the fluid to be pumped. In such constructions the fluid to be pumped, seeking its static level, opens the foot valve and thereby closes the dependently operated head valve. The fluid to be pumped, thus enters the conduit during this filling period, and when the pressure of this fluid against the foot valve is balanced, the pressure fluid opens the head valve and thereby closes the dependently operated foot valve. During the discharge period which is thus inaugurated, the trapped volume of fluid to be pumped, is forced through the conduit to a predetermined point where the load is relieved, as for example by discharging the fluid into a suitable reservoir or container, and when the load is thus relieved the pressure fluid, constituting the fluid piston, is free to expand, and its pressure against the foot valve is thereby reduced so that the pressure of the main body of fluid to be pumped, again seeking its static level,

reopens the foot valve and thereby again closes the dependently operated head valve. The filling period is thus again inaugurated and the cycle of operation is repeated.

In the present invention, while in order to produce the filling period the displacing fluid must have a pressure less than that of the fluid to be pumped, the head and foot valves are not dependently and automatically operated merely by this pressure differential as in pumps of this type heretofore employed. On the contrary, the head valve is controlled by operating means which is preferably in the conduit through which fluid is to be pumped, and which operating means is preferably adjacent the head valve. The operating means may include a driven element connected to the stem of the head valve, with actuation of the operating means preferably controlled, not by mechanical connections such as links or rods, but by energy of a type which may be transmitted via a stationary conductor, e. g., electrical or fluid pressure energy, and if fluid pressure is employed it is other than merely the aforementioned pressure differential. In similar manner the foot valve, if so desired, may be controlled by operating means which may be in the conduit through which fluid is to be pumped, and which operating means may be adjacent the foot valve. Actuation of this operating means is preferably controlled by energy such as electrical or fluid pressure energy, other than merely the pressure differential between the displacing fluid and the fluid which is to be pumped. Consequently, while it is essential that the displacing fluid be regulated so that its pressure is not in excess of that of the fluid to be pumped, seeking its static level during the filling period, still the cycle of operation is in no way dependent upon accurate adjustment of this pressure differential as is required when the head and foot valves are dependently and automatically operated merely by this pressure differential. In the present invention the cycle of operation may be regulated for any desired filling period and any desired discharge period, irrespective of such variations in the static pressure of the fluid to be pumped and/or the pressure of the displacing fluid, as are liable to occur in practical operation of a pump of this type.

More particularly it is an object of the invention to preferably control actuation of the valve operating means by that type of energy which may be transmitted via a stationary conductor, with said conductor leading from the valve operating means to a means which controls transmission of energy via the conductor, with this last

mentioned control preferably remote from the valve operating means.

It is a still further object of the invention to preferably employ a control which automatically functions to provide the alternating filling and discharge periods, and to preferably adapt the automatic control for adjustment to produce a filling period and a discharge period, each of which is of desired interval.

The invention, while of general application, is particularly adapted to lift pumps, since the valvular means for controlling admission of fluid to the conduit through which fluid is to be pumped, and the operating means for said valvular means may be conveniently submerged in the fluid which is to be pumped, by suspending these parts from a string of pipe which is lowered into the fluid, preferably with a conductor for transmitting the energy which controls the operating means, leading to a control at such level higher than the submerged parts of the pump, as will make it conveniently accessible for adjusting the cycle of operation.

By way of illustration, the invention is shown embodied in a pump for an oil well, in which case the fluid to be pumped is the flow from a production stratum in the bore of the well, with said flow including both gas and liquid constituents, and the displacing pressure fluid may be compressed gas, preferably from a suitable source at the earth's surface. For brevity in distinguishing these fluids they will be hereinafter referred to as production fluid and pressure fluid, respectively.

The conduit through which production fluid is elevated by the pump is preferably a usual production string of well tubing extending through usual well casing, and the pressure fluid is supplied to the pump either via a separate tubing located inside or outside the well tubing but inside the well casing, or may be stored in the annular space between the well tubing and the well casing, above a suitable packer, from whence it is supplied to the pump.

Further objects of the invention will be readily understood from the following description of the accompanying drawings, in which:

Fig. 1 is a diagrammatic illustration of the invention, showing the pump and a remote control.

Fig. 2 is a detail axial section through the pump.

Fig. 3 is a transverse section on the line 3—3 of Fig. 2.

Fig. 4 is a view similar to Fig. 2, showing a modified construction.

Fig. 5 is a similar view, showing a still further modification.

Fig. 6 is a similar view, showing a different type of operating means for the head valve.

Fig. 7 is a view similar to Fig. 1, showing a still different type of operating means for the head valve.

Fig. 8 is a similar view, showing a still different type of valve operating means.

Throughout the drawings, and as an instance of the construction when the pump is employed in an oil well, usual well casing is shown at 1, having a string of usual production tubing 2 suspended therein so as to form an annular space 3 between the tubing and the casing. Production fluid from the well is admitted through the lower end of the casing into the lower end of the tubing string in usual manner (not shown), and rises thence through a tail-piece 4 at the lower

end of the tubing string. The production fluid rises in the production string preferably into a tubular housing which is included in the tubing string above the tail-piece, and which is run preferably in with the tubing to a level where a foot valve in the production string, preferably in the tubular housing, is submerged in the production fluid when the latter rises to its static or working level in the tubing string.

In the illustrated embodiment of the invention, the production fluid is pumped through the tubing 2 to the earth's surface, and the pressure fluid which operates the pump is preferably supplied to and stored in the annular space 3, from whence it is admitted to the production string, preferably at the tubular housing of the pump, via a suitable intake. A packer shown diagrammatically at 7, is placed between the tubing 2 and the casing 1 below this intake, to prevent the stored volume of highly compressed pressure fluid from leaking into the production stratum of the formation.

At the top of the well the tubing 2 is connected to a usual head 8 having a discharge conduit 9 for the production fluid which is lifted from the well, with the conduit 9 leading to a container (not shown), e. g., a gas trap, wherein the production fluid is collected and the load is relieved. The head 8 also caps the casing 1, and has a connection 10 whereby pressure fluid, e. g., compressed gas from a suitable source of supply, may be directed into the annular space 3.

The tubular housing and the tubing 2 above the housing form the expansion chamber 6 of the pump, with this expansion chamber communicating at its lower end with the tail piece 4 via a foot valve; and a head valve is mounted in the production string, preferably at the upper portion of the tubular housing and controls admission of pressure fluid from the annular space 3 to the lower portion of the expansion chamber. Operating means for the head valve is preferably also mounted in the production string, preferably in the tubular housing and its actuation preferably is controlled by energy transmitted via a stationary conductor which may extend upwardly through the annular space 3 to the top of the well and thence to suitable control mechanism.

Referring to Figs. 1 and 2, the tubular housing which is incorporated in the tubing string 2, is shown at 5, and the head valve is shown at 14, mounted in a valve housing 15. The housing 15 may be suspended in the tubular housing 5 by means of a nipple 18 at the upper end of the housing 15, connected to a conduit 19 which is preferably integral with that length of the tubing 2 which is next above the housing 5. The upper end of the conduit 19 extends laterally to the wall of tubing 2 and opens therethrough, preferably at a plurality of screen slots 20, so as to form the intake for the pressure fluid which has been stored in the annular space 3. The conduit 19 thus supplies pressure fluid to the nipple 18 which communicates via the head valve 14 with an annular discharge port 22 opening through the wall of the valve housing 15 into the expansion chamber 6. A valve stem 23 depends from the head valve 14, and operating means, suspended from the valve housing 15, cooperates with the valve stem for opening the head valve. The foot valve is shown at 13, mounted in the lower end of the housing 5.

The operating means opens the head valve and holds it open for a predetermined discharge 75

period, actuation of the operating means being independent of pressure differential between the pressure fluid and the production fluid, and at the end of the discharge period the operating means is rendered inoperative to hold the head valve open, this operation being also independent of pressure differential between the pressure fluid and the production fluid. The head valve is then closed, either by the operating means being actuated in the reverse direction, or simply by a force such as spring tension, sufficient to close the head valve when the operating means has been rendered inoperative to hold it open. The head valve then remains closed for a predetermined filling period, being held against opening, irrespective of pressure differential between the pressure fluid and the production fluid, until the operating means is again actuated to open the head valve.

The foot valve closes just prior to or at the time when the head valve is opened by its operating means, and opens at the time or preferably just after the head valve closes, so that the pressure fluid which is admitted to the production string when the head valve is opened, does not force the production fluid back into the formation. For this purpose operating means may close the foot valve at the proper time, or it may simply close responsive to pressure differential between the pressure fluid and the production fluid; and the foot valve may be opened by a spring or other suitable means, or it may simply open responsive to the production fluid again seeking its static level after the force of the pressure fluid has been relieved.

The operation of the pump is as follows:

The housing 5 is run into the well casing until the foot valve 13 is submerged below the static or working level of the production fluid, and with the packer 7 shutting off the production fluid from the annular space 3, pressure fluid is supplied to and stored in this annular space. At the start of the filling period the operating means for holding the head valve open has been rendered inoperative so that the head valve is closed and the foot valve opens. Pressure fluid admitted through slots 20 to the nipple 18 is thus shut off from discharge via port 22 into the expansion chamber 6, and production fluid flows into the production string, i. e. enters the expansion chamber 6, via the open foot valve. The housing 5 is at such level that the production fluid which thus enters the expansion chamber will rise in the tubing 2 to a level above the port 22. After a predetermined filling period, sufficient to fill the production string with production fluid to a level which may be several hundred feet up the tubing 2, and without relying upon pressure differential between the pressure fluid above the closed head valve and the production fluid in the expansion chamber, the operating means for the head valve is actuated to open the head valve, just prior to or at the time at which the foot valve is moved to its closed position, either by a separate operating means or by the increased pressure above the foot valve.

Pressure fluid is thus supplied to the production string via the port 22, and production fluid having been trapped in the production string above the closed foot valve, the pressure fluid forms a fluid piston beneath that volume of production fluid which stands in the tubing 2 above the port 22, and thereby lifts said volume of production fluid through the tubing string 2, for discharge at the conduit 9. During this discharge

period the operating means holds the head valve open for a predetermined interval determined by a control means which renders the operating means inoperative at the end of the desired period so that the head valve then closes, but with said closing of the head valve in no way dependent upon pressure in the tubing string being reduced as a result of the load being relieved when the production fluid has been elevated and discharged. The control means thus terminates the discharge period after a predetermined interval sufficient to elevate and discharge the production fluid through conduit 9, e. g., into a gas separator, and with the head valve then again closed and the foot valve open, the filling period restarts and the cycle of operation is repeated.

In that form of the invention shown at Figs. 1 and 2, the operating means for the head valve 14 is electrically actuated. As an instance of this arrangement the valve stem 23 may terminate in a plunger 26 of a solenoid, the coil of which is shown at 27, suspended from the valve housing 15. The valve housing has a passageway 28 at its intake side whereby the pressure of the displacing fluid which is supplied via nipple 18 is balanced against the head valve, and an annular passageway 29 at the outlet side of the valve housing extends downwardly to the annular port 22 so as to position said port below the head valve in order to prevent production fluid coming in contact with the head valve, there being sufficient leakage of pressure fluid past the head valve to keep the annular space 29 full of pressure fluid at all times. A spring 30 may yieldingly close the balanced head valve.

The solenoid 26-27 is preferably an iron clad solenoid, i. e., one in which the coil windings are completely surrounded by magnetic material; and in order to conserve space the housing 5 preferably forms a part of the magnetic circuit. The coil winding is preferably hermetically sealed, with an annular space between its outer sealing means and the surrounding housing 5, so that this annular space is a part of the expansion chamber 6, permitting passage of the production fluid.

As an instance of this arrangement the core of the solenoid includes ends 32-33 of magnetic material such as mild steel, connected by inner and outer tubes 34-35 having the coil 27 therebetween. The bore of the inner tube 34 receives the solenoid plunger 26, and the outer tube 35 encloses the coil 27 and is radially spaced from the surrounding wall of the housing 5. The tubes 34-35 are welded or otherwise secured to the core-ends 32-33; and the coil assembly as preferably suspended from the valve housing 15, as for example by a threaded coupling 36 having right and left hand threads, with a pin 37 aligning the parts. The tubes 34-35 are of non-magnetic material, preferably stainless steel, and lugs 38 of magnetic material project from the core-ends 32-33 for sliding contact with the housing 5 which is of magnetic material. It is thus the housing 5 and not the outer tube 35, which completes the closed path of magnetic material for the magnetic circuit.

By their pressure tight connections with the core-ends the tubes 34-35 seal the coil winding 27 against external or internal pressure, and consequently there is no need to pack off around the valve stem 23, the pressure from the passageway 28 being free to enter the bore of the tube 34 via a screen 39. By utilizing the housing 5, rather than the outer tube 35, for the mag-

netic circuit, the tube 35 may be of slight thickness occupying but little space, and magnetic leakage from the plunger of the solenoid adjacent the working air gap is appreciably reduced, thereby increasing the pull exerted by the solenoid. Furthermore the tubes 34 and 35 being of the same material, their expansion and contraction will be equal so as not to break their connections with the core ends 32-33; and expansion and contraction is provided for by the lugs 38 freely sliding in the housing 5.

The foot valve 13 of the pump is mounted in the housing 5 below the solenoid 26-27. A spring 40 shown as abutting the lower core-end 33 may yieldingly seat the foot valve, permitting the foot valve to open responsive to pressure of the production fluid seeking its static or working level while the head valve is closed during the filling period, and the spring closes the foot valve when the tension of the spring combined with the static pressure of the column of production fluid in the expansion chamber above the foot valve, exceeds the pressure exerted upwardly against the foot valve by the production fluid rising through the tail piece 4. A spring is preferably employed which will close the foot valve when the production fluid has risen to approximately its static level, and the operating means for the head valve 14 is preferably timed to not open the head valve until just after the spring 40 has closed the foot valve, so that by the time the pressure fluid is admitted to the production string the foot valve is already closed, thereby avoiding excessive shock as might result if the foot valve did not close until downward pressure of the pressure fluid were exerted thereon, and also preventing the pressure fluid exerting back pressure against the production stratum of the well.

A control is provided for the solenoid 26-27, preferably a remote control at the top of the well; and for this purpose a cable 42 may provide the conductor for transmitting electrical energy to the coil winding 27 and may extend through the core-end 32 and the valve housing 15, and thence through the passageway 28 and the conduit 19, into the annular space 3 and thence upwardly along the tubing string 2.

The control may be any desired means for completing an electrical circuit and thereby energizing the solenoid for opening the head valve and holding it open throughout the discharge period, and then breaking the electrical circuit so as to deenergize the solenoid and thus permit the spring 30 to close the balanced head valve throughout the filling period. The control means is preferably automatically operated to provide these alternating filling and discharge periods, and is preferably adjustable to vary said periods, with the adjustments for the respective periods preferably independent of one another.

A preferred type of control means is shown diagrammatically at Fig. 1. Wires 43-44 lead from a source of electrical energy 45-46, the electrical energy being D. C., and suitable means (not shown) being employed to convert A. C. to D. C. in those cases where only A. C. is available. Wires 47-48 provide a circuit for the coil 27, the wire 47 leading from one side of the source of electrical energy to the wire 42 which is connected to the coil 27, and the wire 48 being connected to the tubing 2 on which the other side of the coil 27 is grounded. The wire 48 is connected to the wire 43 via a switch 49, and when,

the switch is closed a circuit is completed for energizing the coil 27 and opening the head valve 14 for the discharge period, and when the switch 49 is open this circuit is broken, thereby deenergizing the coil 27 so that the head valve then closes for the filling period. Opening and closing the switch 49 may be controlled by timers A and B.

The timer A may be adjusted to provide a discharge period of any desired time interval, and the timer B may be separately adjusted to provide a filling period of any desired time interval. As an instance of this arrangement the timers may each include a switch 51 and a cooperating swinging arm 52. The arm 52 is adapted for rotation clockwise by a shaft 53 which is continuously driven at constant speed by suitable means such as an electric motor (not shown) and clockwise rotation of the arm 52 is started and stopped by an electro-magnetic clutch 54. When the arm 52 has been rotated clockwise a predetermined distance as shown at timer B, it engages and opens its cooperating switch 51, and the circuit for its electro-magnetic clutch is thereby broken so that the clutch disengages and thus stops rotation of the arm 52. The arm is then returned to its inoperative position as shown at timer A, as for example by a spring (not shown). A knob 55 may provide for manually circumferentially adjusting the inoperative position of the arm 52 with relation to the operating shaft upon which it is mounted, with the knob then locking the arm relative to its operating shaft in desired adjusted position. The distance traveled by the arm 52 while swinging from its inoperative position to the point where it opens its cooperating switch is thus varied at will, for regulating the time interval during which the timer functions, and the knobs 55 of the respective timers A and B, thus provide for independently adjusting the timers.

The timers are alternately operated, i. e., their electro-magnetic clutches 54 are alternately engaged, as for example by an automatic means which is shown as including contractors C and D; and during the time intervals when the timers A and B are respectively operating, these contractors keep the switch 49 closed and open respectively, so as to provide the discharge period and the filling period. As an instance of this arrangement each contactor has a contact 56, with the contactor C also controlling the switch 49; and each contactor is operated by a coil 57. When the coil of contactor C is energized it opens its contact 56 and closes the switch 49, and when deenergized it closes its contact 56 and opens the switch 49. When the coil of contactor D is energized it opens its contact 56, and when deenergized it closes its contact. The contactors and the timers are electrically connected so that when the coil of one contactor is energized the coil of the other is deenergized, and the coils of the contactors are respectively energized throughout the filling period and the discharge period.

For this purpose the wires 43-44 lead to the electro-magnetic clutches 54 of the timers A and B respectively, and at their opposite sides the clutches of the timers A and B are respectively connected to the contacts 56 of the contactors D and C as shown at 60-61. Wires 62-63 respectively connect the wires 43-44 to the contactors C and D, so that the contactor C controls the main operating circuit for the coil 27 via the switch 49, and via its contact 56 con-

trols the circuit for the electro-magnetic clutch of the timer B, while the contactor D, via its contact 56, controls the circuit for the electro-magnetic clutch of the timer A. The coil 57 of contactor C is connected to the wires 43—60, via a wire 64 and the switch 51 of the timer A, and in similar manner the coil 57 of contactor D is connected to wires 44—61, via a wire 65 and the switch 51 of the timer B.

The wiring diagram shows the position of the parts just as the end of the filling period is approached, the coil 57 of contactor C being de-energized as a result of the contactor 56 of the contactor D being open, thereby opening the switch 49 so that coil 27 is deenergized and the head valve 14 is closed for the filling period. The coil 57 of the contactor C being deenergized, its contact 56 is closed, thereby energizing the coil 57 of the contactor D to open its contact 56. The circuit for the electro-magnetic clutch 54 of the timer A is thus broken, so that its arm 52 remains stationary in its retracted position as shown, and at the same time the circuit for the electro-magnetic clutch 54 of the timer B is closed. The arm 52 of the timer B is thus rotated clockwise to the position shown in the diagram, and the time which it takes for the arm to rotate to a position where it finally opens its cooperating switch 51 determines the filling period. When the switch of timer B is thus opened after a predetermined time interval, the coil 57 of the contactor D is deenergized so that its contact 56 closes. This energizes the coil 57 of the contactor C, closing the switch 49. The coil 27 is thus energized, opening the head valve 14 and starting the discharge period; and the closed contact 56 of the contactor D also energizes the electro-magnetic clutch 54 of the timer A, thereby causing clockwise rotation of the arm 51 of the timer A. The contact 56 of the contactor C is also opened as a result of its coil 57 being energized, thereby breaking the circuit for the electro-magnetic clutch of the timer B so that its arm 52 is returned to its retracted position by its spring (not shown), with its cooperating switch 51 then reclosing, and the retracted arm of the timer B then remaining stationary during the discharge period. The rotating arm 52 of the timer A finally engages and opens its cooperating switch 51, the time interval before this occurs determining the discharge period, and as a result of the switch 51 of the timer A being thus opened, the coil 57 of contactor C is deenergized, reclosing its contact 56 and opening the switch 49. The coil 27 is thus deenergized so that the head valve 14 closes to again start the filling period, and the electro-magnetic clutch 54 of the timer B is reengaged to again cause clockwise rotation of the arm 52 of the timer B. The coil 57 of the contactor D is also energized as a result of the contact 56 of the contactor C closing, thereby opening the contact 56 of the contactor D. The electro-magnetic clutch 54 of the timer A is thus disengaged so that the arm 52 of this timer is retracted by its spring, and the switch 51 of the timer A thus recloses and the cooperating arm 52 then remains stationary in its retracted position during the filling period. The parts are then again in the position originally described, so that rotation of the arm 52 of the timer B again controls the filling period.

At Fig. 4 a modification of the invention is shown, particularly applicable to a well struc-

ture wherein it may be desired to position the foot valve an appreciable distance below the packer 7. This packer must be placed above the level at which the well casing is open to the surrounding formation, in order to prevent escape of pressure fluid from the annular space 2, and the intake whereby this pressure fluid is directed into the valve chamber of the head valve must be above the packer. If then it is desired to position the foot valve at a much lower level but at the same time admit the pressure fluid to the production string at a level which is only a comparatively short distance above the foot valve, it is necessary, with the structure shown at Figs. 1 and 2, to suspend the head valve housing and its operating means an appreciable distance below the conduit 19, as for example by elongating the connecting nipple which is provided at the upper end of the valve housing. This necessitates the cable 42 being threaded through this elongated nipple in order that it may be connected to the coil 27. But with the structure shown at Fig. 4 only a short length of the cable need be threaded through the housing for the head valve, even though the foot valve is positioned at a level far below that of the packer 7.

As an instance of this arrangement, the conduit 19a, provided with the screen slots 20a, opens upwardly into the valve housing 15a which may be an integral part of the conduit 19a, and the actuating solenoid 26a—27a, which may be similar to that previously described except that it is inverted, and which has its parts indicated by reference numerals 32a, 33a, etc., is mounted in the housing 5a above the valve housing 15a, and is connected to the valve housing by a coupling 36a. The head valve 14a is a balanced valve, closed by a spring 30a and opened by its cooperating solenoid when the latter is energized, and the cable 42a for the coil of the solenoid extends through the valve housing 15a and the conduit 19a, and thence into the annular space 3 and upwardly along the tubing 2 so that it may be connected to a control means such as previously explained in connection with Figs. 1 and 2. The outlet side of the head valve has a depending passageway 29a terminating in a nipple 70, from which a conduit 71 of any desired length may be suspended so as to form a discharge 22a through which pressure fluid may be directed into the production string, preferably at the expansion chamber 6a. The foot valve 13a is mounted in an extension 72 of the housing 5a, and this extension may be of any desired length so as to position the foot valve at any desired level. The foot-valve is shown as closing by gravity when the production fluid rising in the production string balances the pressure against the valve; and as previously described the control means is preferably timed to open the head valve and thus inaugurate the discharge period, just after the foot valve has closed.

In the modification of the invention shown at Fig. 5, the head valve and the solenoid for actuating the same, are mounted in housing 5b and comprise an assembly the same as illustrated at Figs. 1 and 2 and denoted by reference numerals 14b, 26b, 27b, etc., but the foot valve, which is shown at 13c, has a positive operating means for closing the foot valve at any desired time. As an instance of this arrangement the foot valve may be electrically operated, as for example by a

solenoid which is energized to close the foot valve throughout the discharge period, and which is deenergized to permit the foot valve to open throughout the filling period. The foot valve is mounted in a valve housing 74 at the lower end of the housing 5b, and the valve housing 74 has an intake 75 communicating with the foot piece 4 and providing a balanced valve, with the outlet of the valve housing communicating with the expansion chamber 6b as shown at 76. The stem 77 of the foot valve projects upwardly through a screen 78 and terminates in the plunger of a solenoid; and a spring 81 yieldingly opens the foot valve for the filling period, and the solenoid when energized closes the foot valve for the discharge period.

The solenoid for the foot valve is preferably a structure similar to that of the solenoid assembly for the head valve which is shown at Figs. 2 and 3, except that it is inverted. Its core-ends 32c-33c are connected by inner and outer tubes 34c-35c of non-magnetic material, enclosing the coil winding 27c which actuates the plunger 26c; and the solenoid assembly is supported upon the valve housing 74 by a coupling 36c, and has lugs 38c slidably engaging the wall of housing 5b so that the latter forms a part of the magnetic circuit. The solenoid for the foot valve may be controlled by the same type of control means as employed with the solenoid for the head valve; and for this purpose a cable 42c may be connected to the coil 27c and may extend to the exterior of the housing 5b. The cable 42c, and the cable 42b for the solenoid of the head valve, may extend upwardly along the tubing 2 and at the earth's surface may be connected to separate control means each of which may be of the type shown at Fig. 1.

When the control means for the head valve causes the coil 27b of its solenoid to be energized; the head valve is opened to initiate the discharge period as previously described; and the control means for the foot valve is timed, so that simultaneously or just prior thereto, the coil 27c is energized to close the foot valve. At the end of the discharge period, the control means for the head valve deenergizes its coil 27b so that the balanced head valve is closed by its spring, and the control means for the foot valve also deenergizes the coil 27c so that the spring 81 opens the balanced foot valve in properly timed relation to the closing of the head valve, thereby inaugurating the filling period. The timing is preferably such that the foot valve is opened just after the head valve has been closed.

If the pressure fluid is under extremely high pressure, the construction as thus far described might require the use of such a strong spring for the head valve, in order to avoid excessive head valve leakage, as would require a more powerful solenoid than might be practical for the restricted space available. In order to avoid an excessively large solenoid and at the same time insure operation of the head valve without excessive leakage, the construction shown at Fig. 6 may be employed. With this arrangement the operating means for the head valve includes a solenoid such as previously described and a piston which is actuated by the pressure fluid which is utilized for operating the pump. The solenoid controls admission of the pressure fluid for actuating the piston which is connected to the stem of the head valve, and the electrical energy which is supplied to the solenoid is remotely controlled as previously described.

As an instance of this arrangement, a housing 15d for the head valve is suspended in housing 5d, from an intake conduit 19d as previously described, and a solenoid assembly such as previously described and including plunger 26d and coil 27d, is suspended from the head valve housing by a coupling 36d. The head valve 14d closes downwardly and pressure against the valve is not balanced, the valve housing having an inlet space 28d above the head valve and an outlet passageway 29d below the head valve, with the outlet passageway leading downwardly to a discharge port 22d which communicates with the expansion chamber 6d. The head valve is yieldingly seated by a spring 30d, and its depending stem 23d terminates in a piston 85 which is adapted for reciprocation in a cylinder 86 formed in the housing 15d below the head valve. The stem 23d is loosely packed as shown at 87, so as to prevent sand entering the cylinder 86 while permitting flow of pressure fluid between the upper end of the cylinder and the outlet passageway 29d; and a bore 88 opens into the lower end of the cylinder 86, and is preferably provided with a check valve 89 which closes against escape of pressure from the lower end of the cylinder. The bore 88 forms a valve seat 90 and communicates with a bore 91 which in turn opens into the inlet space 28d, and a needle type of pilot valve 92 cooperates with the valve seat 90 and has a depending valve stem 93 which terminates in the plunger 26d of the solenoid. A spring 94 yieldingly closes the needle type pilot valve 92, which is opened against the tension of its spring when the coil 27d of the solenoid is energized, and a cable 42d provides a connection for the coil of the solenoid, and may lead to a control means such as shown at Fig. 1. The foot valve 13d may be of the type shown at Fig. 2.

At the beginning of the filling period the coil 27d is deenergized by the control means as explained in connection with Fig. 1. The needle valve 92 is thus closed by its spring for shutting off the supply of pressure fluid to the lower end of the cylinder 86, and the pressure fluid supplied to the lower end of the cylinder during the preceding discharge period soon leaks past the piston 85 and thence into the outlet passageway 29d, so that the spring 30d closes the head valve 14d, and then keeps the head valve closed throughout the filling period. At the end of the filling period the control means causes the coil 27d to be energized in the same manner as explained in connection with Fig. 1, thereby opening the valve 92 and admitting pressure fluid to the lower end of the cylinder 86. The piston 85 is of greater area than that of the head valve 14d, whereby this upward pressure against the piston opens the head valve to inaugurate the discharge period. Pressure fluid being thus admitted to the expansion chamber 6d for lifting the production fluid, back pressure builds up in the passageway 29d and tends to balance the head valve so that its spring 30d starts to close the head valve. But this closing movement throttles the pressure fluid, producing a pressure drop through the head valve resulting in a pressure differential above and below the piston 85. The piston thus exerts an upward thrust, sufficient to balance the spring 30d, and the head valve is balanced and floats in its partially open position, thereby continuing the discharge period. To prevent vibration when the head valve is in this open balanced position, the check valve 89 is preferably employed to insure stability. At the

end of the discharge period the coil 27d is again deenergized by the control means, thereby again starting the filling period.

In the modification of the invention shown at Fig. 7 the head valve is operated by means which positively opens the head valve during the discharge period and which then positively closes the head valve during the filling period. For this purpose the arrangement may be similar to that shown at Fig. 2, except that the spring for the head valve is omitted and the operating means for the head valve is an electric motor in lieu of the solenoid previously described.

As an instance of this arrangement the head valve 14e is mounted in a valve housing 15e which is suspended in housing 5e from an intake conduit 19e as previously described, the construction providing a balanced valve adapted for discharge of pressure fluid into the expansion chamber 6e via the discharge port 22e, when the head valve is open. The depending stem 23e of the head valve has a thread 100 of coarse pitch, threaded through a nut 101 which is fixed against rotation or vertical movement in the lower portion of the valve housing 15e; and the lower end of the valve stem is splined to a shaft 102 as shown at 103, so that the valve stem is rotated by the shaft but is free for axial movement relative thereto. A housing 104 is suspended from the valve housing 15e by a coupling 36e, and preferably has lugs 38e slidably engaging the wall of the housing 5e. An electric motor 105 is mounted in the housing 104 and rotates the shaft 102 through speed reducing gearing 106. A cable 42e may supply electrical energy to the motor 105, and preferably extends into the annular space 3 and thence upwardly along the tubing string 2 to a suitable control.

At the beginning of the filling period the control means closes a circuit which causes rotation of the motor in one direction for rotating the shaft 102 in the direction for threading the stem 23e through the nut 101 so as to close the head valve 14e. The motor is preferably a torque motor which will stop when the head valve has been closed, and the head valve then remains closed throughout the remainder of the filling period. At the start of the discharge period the control means closes a circuit which causes reverse rotation of the motor, thereby rotating the shaft 102 in the opposite direction and thus threading the stem 23e through the nut 101 in the direction to open the head valve. The torque motor will stop when the head valve has been opened, and the head valve then remains open throughout the discharge period, at the end of which the control means again inaugurates the filling period. The foot valve 13e employed in this construction may be of the same type as shown at Fig. 2.

The motor is preferably a three-phase motor having motor leads 110—111—112 connected via the control means to a source of electrical energy 113—114—115; and the control means is adapted to reverse a pair of these leads at the start of the filling period and at the start of the discharge period, for rotating the motor in opposite directions. The control means preferably also includes time relay relays, respectively opening the main circuit after the torque motor has been rotated in each of its opposite directions and then stopped, and whereby overheating is avoided.

As an instance of this arrangement the control means may include timers A'—B' and con-

tactors C'—D' which are in general similar to corresponding parts of the control shown at Fig. 1, the similar elements being indicated at Fig. 7 by primed reference numerals. Wires 43'—44' lead from the terminals 113—114, and the contactors C'—D' with their contacts 56', and the timers A'—B' with their electro-magnetic clutches 54' and their swinging arms 52' and their cooperating switches 51', are connected to these wires as previously described. In lieu of the switch 49 employed in the construction shown at Fig. 1, each of the contactors C'—D' preferably has a second contact 116, and when the coil of either of the contactors is energized, its contact 56' is open and its contact 116 is closed, and when deenergized its contact 56' is closed and its contact 116 is open. Time delay relays E and F are preferably employed with the contactors, and each includes a coil 117, which when energized opens a switch 118 after a time interval, which may preferably be adjusted by suitable means (not shown), and which when deenergized permits its switch 118 to close. The coil 117 of time delay relay E is in circuit with wires 43'—64', and the coil of relay F is in circuit with wires 44'—65'. The switch 118 of relay E is between the contact 116 of contactor C and a wire 119 which leads to a coil 122, the other side of which is connected to wire 44'; and the switch 118 of relay F is between the contact 116 of contactor D and a wire 120 which leads to a coil 121, the other side of which is connected to the wire 43'. The coil 121 when energized closes switches 123—124, and the coil 122 when energized closes switches 125—126. The switch 123 connects the wire 43' to the lead 110, and the switch 124 connects the wire 44' to the lead 111. The switch 125 connects the wire 43' to the lead 111, and the switch 126 connects the wire 44' to the lead 110. The lead 112 is connected to the terminal 115.

The wiring diagram (Fig. 7) shows the position of the parts just at the start of the filling period, with the timer B' operating to determine the length of the filling period by finally opening its switch 51', and with the coil of contactor D energized so that its contact 116 is closed, thereby energizing the coil 121 so that electrical energy is supplied to the motor 105, with the leads 110—111—112 connected to terminals 113—114—115 in the order mentioned. By this arrangement the motor is rotated in the direction to close the head valve 14e and thus inaugurate the filling period, and after a time interval determined by the adjustment of relay F, and by which time the head valve will have been closed and the torque motor will have stopped rotating, the switch 118 of relay F opens (the coil of said relay having been energized at the same time as that of the coil of contactor D), thereby breaking the circuit for the coil 121 so that the switches 123—124 are opened, thus breaking the main power circuit for the motor. The head valve then remains closed for the remainder of the filling period, with the motor 105 idle.

At the end of the filling period the arm 52' of timer B opens its cooperating switch 51', thereby deenergizing the coil of contactor D and energizing the coil of contactor C as previously explained in connection with Fig. 1. The timer A then starts to operate to determine the length of the discharge period, which is inaugurated by the closed contact 116 of contactor C, closing the circuit for the coil 122. This coil when en-

energized closes the switches 125—126, thus connecting the terminals 113—114—115 to the leads 111—110—112 in that order, and thereby supply current to the motor 105 for driving it in the reverse direction. The motor thus opens the head valve to start the discharge period, and at the time when the torque motor is stopped by the valve having reached its full open position, the time delay relay E operates to open its switch 118, thereby breaking the circuit for coil 122 and thus opening the switches 125—126 so as to break the main operating circuit for the motor. The head valve then remains open for the remainder of the discharge period, with the motor 105 idle, and until the filling period is again inaugurated by the arm 52' of the timer A' engaging and opening its cooperating switch 51'. When this occurs and as previously explained in connection with Fig. 1, the coil of contactor C is deenergized and the coil of contactor D is again energized, so that the parts are again in the position shown in the diagram (Fig. 7), ready for the filling period.

In the modification of the invention shown at Fig. 8 the head valve is opened by operating means, actuation of which is controlled by fluid pressure other than the displacing fluid which operates the pump, and this fluid pressure is transmitted to the operating means through a tube extending to the top of the well, and is controlled at the top of the well so that the operating means opens the head valve throughout the discharge period and then permit the head valve to close during the filling period.

As an instance of this arrangement the head valve 14f is mounted in a valve housing 15f which is suspended in housing 5f from an intake conduit 19f. A spring 30f tends to seat the head valve so as to shut off the intake chamber 28f to the outlet passageway 29f, and the outlet passageway leads downwardly to a discharge port 22f which opens into the expansion chamber 5f. The depending valve stem 23f terminates in a piston 130 which is adapted for reciprocation in a cylinder 131, and this cylinder may be formed in the lower part of the valve housing 15f. Fluid pressure may be supplied to the lower end of the cylinder 131 via a tube 133, with this tube extending to the exterior of the housing 5f and thence upwardly along the tubing string 2 to a remote control. A suitable fluid may be stored in the tube 133, with its static pressure which is directed upwardly against the piston 130 tending to open the head valve, but the spring 30f seats the head valve against this static pressure when no additional operating pressure is exerted on the fluid in the tube 133, thereby keeping the head valve closed during the filling period. At the start of the discharge period operating pressure is exerted on the fluid in the tube 133, thereby increasing its pressure against the piston 130 so that the head valve is opened against the tension of its spring, and this operating pressure is then maintained so as to keep the head valve open for the duration of the discharge period. At the end of the discharge period the operating pressure is relieved so that the spring 30f again seats the head valve against the static pressure in the tube 133, thereby again inaugurating the filling period.

The operating pressure may be supplied by any suitable means, and as an instance of this arrangement the tube 133 may communicate with a cylinder 134 in which a piston 135 is adapted for reciprocation to alternately relieve and exert

pressure on the fluid in the tube. In order to keep the tube full of fluid against any leakage losses, a reservoir 136 may communicate with the cylinder 134 via a port 137, the port being open when the piston 135 is retracted to relieve the operating pressure, and being closed by the piston when the latter is projected to exert pressure on the fluid in the tube. The piston 135 may be reciprocated by any suitable actuating means, and the actuating means has a suitable control whereby it projects the piston 135 for a discharge period of any desired time interval, and then permits retraction of the piston for any desired filling period.

By way of illustration the actuating means is shown as fluid pressure, and for this purpose a piston 138 may be connected to the piston 135 with the piston 138 adapted for reciprocation in a cylinder 139, and fluid pressure may be supplied to or relieved from the cylinder 139 so as to project the piston 135 or permit its retraction. As an instance of this arrangement a three-way valve 140 may have an intake 141 connected to a source of fluid pressure, with a conduit 142 connecting the valve and the cylinder 139, and with an exhaust 143 leading from the valve. A reciprocating valve head 144, when moved in one direction closes the exhaust 143 and opens the intake 141 to the conduit 142 whereby fluid pressure actuates the piston 138 so as to exert pressure in the tube 133 for opening the head valve 14f, and when moved in the opposite direction closes the intake 141 and opens the conduit 142 to the exhaust 143 whereby fluid pressure is exhausted from the cylinder 139 so that the operating pressure in tube 133 is relieved, thereby permitting the head valve 14f to close.

Means are provided for shifting the valve head 144 in opposite directions at predetermined time intervals, and for this purpose a solenoid 145, when energized, may shift the valve head 144 so as to supply fluid pressure to the cylinder 139 and thereby open the head valve 14f to provide the discharge period, and when deenergized permits movement of the valve head 144 to shut off the supply of fluid pressure and exhaust the cylinder 139, whereby the head valve 14f is closed to provide the filling period. The solenoid 145 may be controlled by means similar to that shown at Fig. 1, such a control means being indicated generally at G and showing the knobs 55" for its timers A" and B" whereby the time interval of the filling period and the discharge period may be independently adjusted as previously explained, and showing the wires 47"—48" which lead to the solenoid 145 for controlling the same.

In this form of the invention the foot valve 13f may be of the type shown at Fig. 4.

The various embodiments of the invention as thus described provide for controlling the filling and discharge periods of a displacement pump wherein a fluid which is to be pumped is admitted to a production string during the filling period and is then displaced by a pressure fluid during the discharge period, and the invention provides for alternately inaugurating the filling and discharge periods independently of pressure differential between the displacing fluid and the fluid which is to be pumped. Consequently it is not necessary to accurately regulate the pressure of the displacing fluid with relation to the static pressure of the fluid which is to be pumped, in order to produce the alternating filling and discharge periods, and therefore the time intervals

of these alternating periods are not restricted to exactly those intervals at which the proper pressure differentials may be automatically obtained. The alternating filling and discharge periods may each consume any desired time interval, and may be independently adjusted at will.

The invention is particularly applicable to a production string for a well, with the filling and discharge periods controlled by valvular means which is preferably in the production string, adjacent the expansion chamber of the production string, with operating means for the valvular means preferably in the production string and adjacent the valvular means, and with actuation of the operating means preferably controlled by energy of a type which may be transmitted via a stationary conductor, e. g. a wire conducting electrical energy to the operating means or a tube conducting fluid pressure energy to said operating means, and with the conductor preferably leading to a remote means for controlling the energy which is supplied to the conductor.

I claim:

1. In a fluid pressure displacement pump, an expansion chamber, means for alternately supplying the expansion chamber with a pressure fluid and with a fluid which is to be pumped, means adjacent the expansion chamber for operating the fluid supplying means so as to independently control the time intervals during which the respective fluids are admitted, said operating means being adapted for control by energy of a type which may be transmitted via a stationary conductor, and means transmitting energy of said type to the operating means.

2. In a fluid pressure displacement pump, an expansion chamber, means for alternately supplying the expansion chamber with a pressure fluid and with a fluid which is to be pumped, means adjacent the expansion chamber for operating the fluid supplying means so as to control the time intervals during which the respective fluids are admitted, said operating means being adapted for control by energy of a type which may be transmitted via a stationary conductor, means for transmitting energy of said type to the operating means, and means for controlling the transmission of energy so as to independently vary said time intervals for admission of the respective fluids.

3. In a fluid pressure displacement pump, a housing forming an expansion chamber, a valve controlling admission of fluid to the expansion chamber, a solenoid for operating the valve, the solenoid being mounted in the housing in spaced relation from the wall thereof, the solenoid being iron clad and hermetically sealed, the wall of the housing being of magnetic material, and bridges of magnetic material between the solenoid and the wall of the housing whereby said wall forms a part of the magnetic circuit.

4. In a fluid pressure displacement pump, an expansion chamber having an inlet and an outlet and adapted for incorporation in a well production string with its inlet providing for admission of production fluid from the well and with its outlet communicating with the production string and providing for flow of production fluid from the expansion chamber through the production string to the top of the well, a valvular control preventing discharge of production fluid from the expansion chamber via the inlet, a valve controlling admission of pressure fluid to the expansion chamber, means for operating the valve, the valve and its operating means being

mounted in the expansion chamber for flow of production fluid therethrough past the operating means and thence to the outlet of the expansion chamber, a stationary conductor transmitting energy to the operating means for controlling its actuation, means at the top of the well for automatically controlling transmission of said energy so as to independently control the time intervals during which the operating means maintains the valve open and closed respectively, the automatic control operating independently of fluid admitted to the expansion chamber, and means for adjusting the automatic control for independently varying said respective time intervals.

5. In a fluid pressure displacement pump, an expansion chamber having an inlet and an outlet and adapted for incorporation in a well production string with its inlet providing for admission of production fluid from the well and with its outlet communicating with the production string and providing for flow of production fluid from the expansion chamber through the production string to the top of the well, a valvular control preventing discharge of production fluid from the expansion chamber via the inlet, a valve controlling admission of pressure fluid to the expansion chamber, means for operating the valve, the valve and its operating means being mounted in the expansion chamber for flow of production fluid therethrough past the operating means and thence to the outlet of the expansion chamber, and a stationary conductor transmitting energy to the operating means for controlling its actuation, the transmission of energy via the stationary conductor being independent of pressure of fluid supplied to the expansion chamber via the valve.

6. In a fluid pressure displacement pump, an expansion chamber having an inlet and an outlet and adapted for incorporation in a well production string with its inlet providing for admission of production fluid from the well and with its outlet communicating with the production string and providing for flow of production fluid from the expansion chamber through the production string to the top of the well, a valvular control preventing discharge of production fluid from the expansion chamber via the inlet, a valve controlling admission of pressure fluid to the expansion chamber, means for operating the valve, the valve and its operating means being mounted in the expansion chamber for flow of production fluid therethrough past the operating means and thence to the outlet of the expansion chamber, a stationary conductor transmitting energy to the operating means for controlling its actuation, and means at the top of the well for controlling transmission of said energy, the last mentioned means operating independently of fluid admitted to the expansion chamber.

7. In a fluid pressure displacement pump, an expansion chamber having an inlet and an outlet providing respectively for admission and discharge of a fluid which is to be pumped, a valve adjacent the expansion chamber for controlling admission of pressure fluid thereto, means adjacent the valve for operating the same, a stationary conductor transmitting energy to the operating means for controlling its actuation and means for automatically controlling transmission of said energy so as to independently control the time intervals during which the operating means maintains the valve open and closed respectively.

8. In a fluid pressure displacement pump, an

expansion chamber having an inlet and an outlet providing respectively for admission and discharge of a fluid which is to be pumped, a valve adjacent the expansion chamber for controlling admission of pressure fluid thereto, means adjacent the valve for operating the same, a stationary conductor transmitting energy to the operating means for controlling its actuation, the transmission of energy via the stationary conductor being independent of pressure of fluid supplied to the expansion chamber via the valve, means for automatically controlling transmission of said energy so as to control the time intervals during which the operating means maintains the valve open and closed, and means for adjusting the automatic control for varying said time intervals.

9. In a fluid pressure displacement pump, an expansion chamber having an inlet and an outlet providing respectively for admission and discharge of a fluid which is to be pumped, a valve adjacent the expansion chamber for controlling admission of pressure fluid thereto, means adjacent the valve for operating the same, a stationary conductor transmitting energy to the operating means for controlling its actuation, means for automatically controlling transmission of said energy so as to independently control the time intervals during which the operating means maintains the valve open and closed respectively, and means for adjusting the automatic control for independently varying said respective time intervals.

10. In a fluid pressure displacement pump, an expansion chamber having an inlet and an outlet providing respectively for admission and discharge of a fluid which is to be pumped, a valve adjacent the expansion chamber, means for operating the valve, said valve when open admitting pressure fluid to the expansion chamber and when closed preventing pressure fluid entering or escaping from the expansion chamber via said valve, a stationary conductor transmitting energy to the operating means for controlling its actuation, and means for controlling transmission of said energy so as to independently control the time intervals during which the operating means maintains the valve open and closed respectively.

11. In a fluid pressure displacement pump, an expansion chamber, a valve controlling admission of fluid to the expansion chamber, and a solenoid for operating the valve, the solenoid being mounted in the expansion chamber in spaced relation from the wall thereof.

12. In a fluid pressure displacement pump, an expansion chamber, a valve controlling admission of fluid to the expansion chamber, a solenoid for operating the valve, the solenoid being mounted in the expansion chamber in spaced relation from the wall thereof, the solenoid being iron clad, the wall of the expansion chamber being of magnetic material, and bridges of magnetic material between the solenoid and the wall of the expansion chamber whereby said wall forms a part of the magnetic circuit.

13. In a fluid pressure displacement pump, a conduit having an intake for production fluid and an intake for pressure fluid, a valve for at least one of said intakes, means for operating the valve, and means for automatically controlling the operating means so as to independently control the time intervals during which the valve is open and closed respectively.

14. In a fluid pressure displacement pump for

a well, a production string in the well having an intake for production fluid and an intake for pressure fluid, a valve for at least one of said intakes, means in the well for operating the valve, and means for automatically controlling the operating means so as to independently control the time intervals during which the valve is open and closed respectively.

15. In a fluid pressure displacement pump, a conduit for fluid which is to be pumped, a valve for admitting pressure fluid to the conduit when said valve is open, and preventing pressure fluid entering or escaping from the conduit via said valve when the valve is closed, means for operating the valve, and means for independently controlling the time intervals during which the valve is open and closed respectively.

16. In a fluid pressure displacement pump, a conduit having an intake for production fluid and an intake for pressure fluid, a valve for at least one of said intakes, means for operating the valve, means for automatically controlling the operating means so as to independently control the time intervals during which the valve is open and closed respectively, and means for adjusting the automatic control for independently varying said respective time intervals.

17. In a fluid pressure displacement pump, a conduit having an intake for production fluid and an intake for pressure fluid, a valve for at least one of said intakes, means for operating the valve, a stationary conductor transmitting energy to the operating means for controlling its actuation, the transmission of energy via the stationary conductor being independent of pressure of fluid supplied to the conduit via the valve, means for automatically controlling transmission of said energy so as to control the time intervals during which the valve is open and closed respectively, and means for adjusting the automatic control for varying said time intervals.

18. In a fluid pressure displacement pump for a well, a production string in the well having an intake for production fluid and an intake for pressure fluid, a valve for at least one of said intakes, means in the well for operating the valve, a stationary conductor transmitting energy to the operating means for controlling its actuation, the transmission of energy via the stationary conductor being independent of pressure of fluid admitted to the production string, means for automatically controlling transmission of said energy so as to control the time intervals during which the valve is open and closed respectively, and means for adjusting the automatic control for varying said time intervals.

19. In a fluid pressure displacement pump, a conduit having an intake for production fluid and an intake for pressure fluid, a valve for at least one of said intakes, means for operating the valve, the valve and its operating means being mounted in the conduit, and a stationary conductor transmitting energy to the operating means for controlling its actuation, the transmission of energy via the stationary conductor being independent of pressure of fluid admitted to the conduit.

20. In a fluid pressure displacement pump for a well, a production string in the well having an intake for production fluid and an intake for pressure fluid, a valve for at least one of said intakes, means in the well for operating the valve, a stationary conductor transmitting energy to the operating means for controlling its actuation, the transmission of energy via the sta-

tionary conductor being independent of pressure of fluid admitted to the production string, and means for controlling transmission of energy via the stationary conductor, said last mentioned means operating independently of fluid admitted to the production string.

21. In a fluid pressure displacement pump, a conduit having an intake for production fluid and an intake for pressure fluid, a valve for at least one of said intakes, a solenoid for operating the valve, the solenoid being mounted in the conduit in spaced relation from the wall thereof, the wall of the conduit being of magnetic material, and bridges of magnetic material between the solenoid and the wall of the conduit whereby said wall forms a part of the magnetic circuit.

22. In a fluid pressure displacement pump, a conduit for fluid which is to be pumped, a valve controlling admission to the conduit of fluid which is to be pumped, a valve controlling admission of pressure fluid to the conduit, and means for operating the valves so as to alternately admit the respective fluids, said operating means providing for independently controlling the time intervals during which the respective fluids are admitted.

23. In a fluid pressure displacement pump, a conduit for fluid which is to be pumped, a valve controlling admission to the conduit of fluid which is to be pumped, a valve controlling admission of pressure fluid to the conduit, means for operating the valves so as to alternately admit the respective fluids, said operating means providing for independently controlling the time intervals during which the respective fluids are admitted, and means for independently varying said respective time intervals.

24. In a fluid pressure displacement pump for a well, a production string in the well, a valve in

the well for admitting pressure fluid to the production string when the valve is open and preventing pressure fluid entering or escaping from the production string via said valve when the valve is closed, means in the well for operating the valve, and a stationary conductor transmitting energy to the operating means for controlling its actuation, the transmission of energy via the stationary conductor being independent of pressure of fluid admitted to the production string.

25. In a fluid pressure displacement pump for a well, a production string in the well, a valve in the well controlling admission of pressure fluid to the production string, means in the well for operating the valve by fluid pressure, a valve in the well for controlling admission of said fluid pressure to the operating means, and means for actuating the last mentioned valve independently of fluid in the production string and by energy of a type which may be transmitted via a stationary conductor, and means for transmitting energy of said type to the actuating means.

26. In a fluid pressure displacement pump for a well, a production string in the well, a conduit for supplying pressure fluid to the production string, a valve in the well controlling admission of pressure fluid from the conduit to the production string, means in the well for operating the valve by fluid pressure, a second conduit containing a fluid and communicating with said operating means, and means for controlling the pressure of the fluid in the second conduit, said controlling means being operable independently of fluid in the production string and independently of movement of the operating means.

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