Oct. 20, 1931. E. R. WOLCOTT 1,827,925

APPARATUS FOR PUMPING LIQUIDS

Filed Feb. 18, 1929 3 Sheets-Sheet 1

Fig. 1

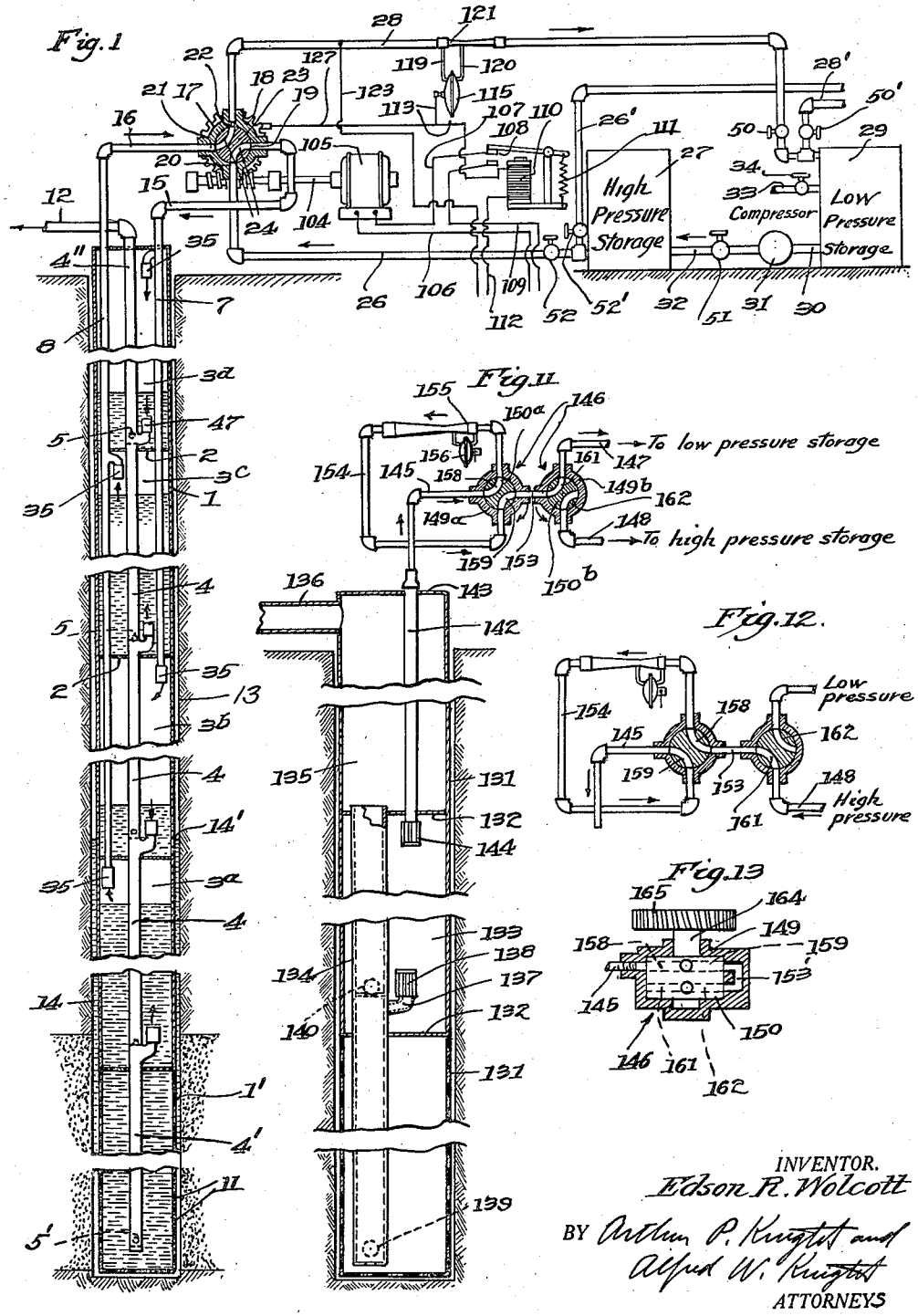


Fig. 11

Fig. 12.

Fig. 13

INVENTOR.
Edson R. Wolcott
BY Arthur P. Knight and Alfred W. Knight
ATTORNEYS

Oct. 20, 1931. E. R. WOLCOTT 1,827,925

APPARATUS FOR PUMPING LIQUIDS

Filed Feb. 18, 1929 3 Sheets-Sheet 2

Fig. 2.

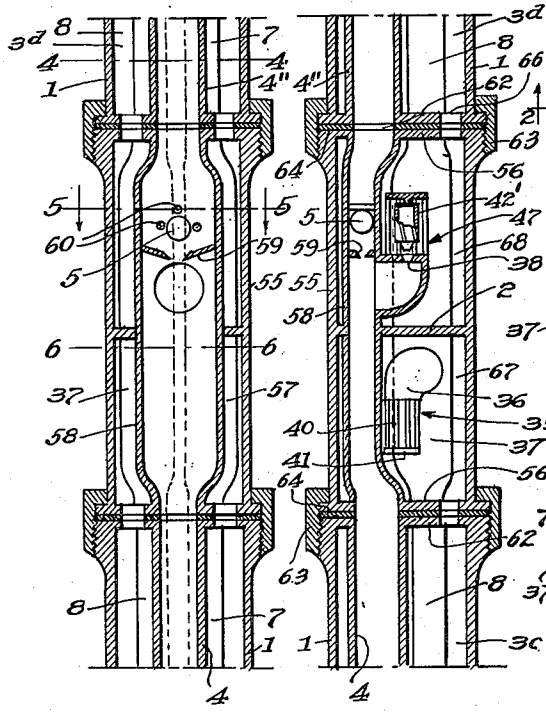


Fig. 3.

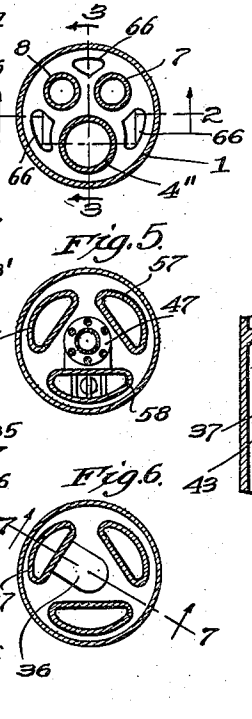


Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

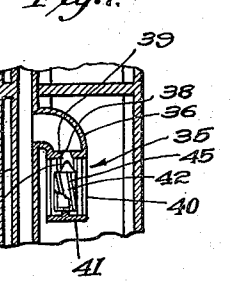


Fig. 8.

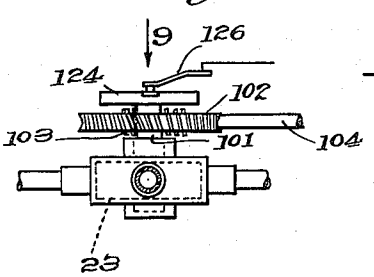


Fig. 9.

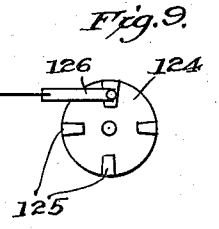
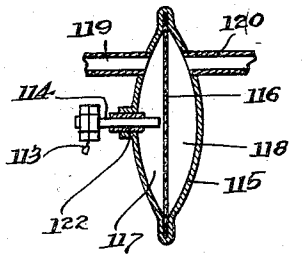


Fig. 10.



INVENTOR.
Edson R. Wolcott,
BY Arthur P. Knight and
Alfred W. Knight
ATTORNEYS

Oct. 20, 1931. E. R. WOLCOTT 1,827,925

APPARATUS FOR PUMPING LIQUIDS

Filed Feb. 18, 1929 3 Sheets-Sheet 3

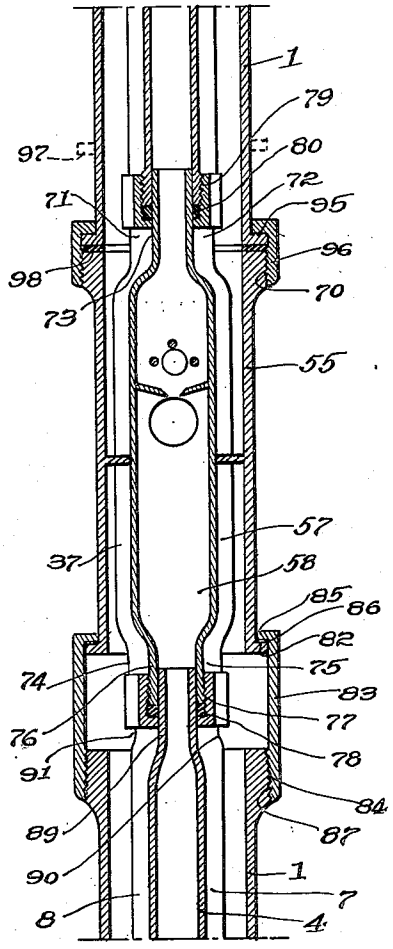


Fig. 14.

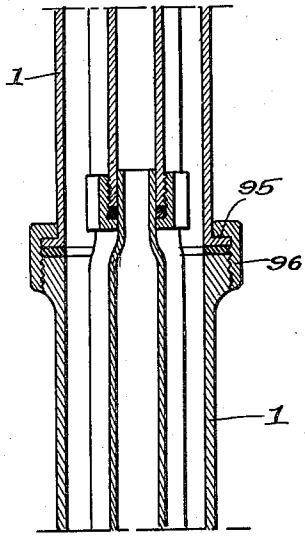


Fig. 15.

INVENTOR.
Edson R. Wolcott,
BY Arthur P. Knight and
Alfred W. Knight
ATTORNEYS

Patented Oct. 20, 1931 1,827,925

UNITED STATES PATENT OFFICE

EDSON R. WOLCOTT, OF LOS ANGELES, CALIFORNIA

APPARATUS FOR PUMPING LIQUIDS

Application filed February 18, 1929. Serial No. 340,711.

This invention relates to apparatus for pumping liquids and particularly to multi-stage apparatus of the type described in my United States Patent No. 1,628,943 issued May 17, 1927 for pumping liquids through considerable vertical heights, as in pumping oil or other liquid from wells of relatively great depth. While the invention described in said patent and the present improvements thereto are particularly adapted for the pumping of oil from oil wells, the same may also be advantageously used for pumping other liquids.

The principal object of this invention is to provide for automatic control of a pumping apparatus of the type described in said patent, and to cause a full charge of oil to be delivered from each stage of the pump to the next at each cycle.

A further object is to prevent loss of the gaseous medium used to effect the pumping operation.

A further object is to provide a novel form of self-cleaning float valve for use in apparatus of this sort.

The pumping apparatus described in said prior patent comprises essentially a casing extending to the desired depth in the well and provided with suitably spaced horizontal partitions dividing the interior of said casing into super-posed contiguous working chambers, means for conducting liquid from the lower portion of each of said pump chambers to the lower portion of the next higher pump chamber and provided with check valve means for preventing downward flow of liquid therethrough, two pipes or gas passage means extending throughout the major portion of the height of said casing and communicating respectively with alternate pump chambers, means for creating conditions of relatively high pressure and relatively low pressure in the respective gas passage, means whereby alternate pump chambers are subjected to relatively high and relatively low pressures, and means for periodically reversing the conditions of relatively high and relatively low pressure in the respective gas passage. Means are also provided for admitting liquid from around the casing to the lowermost pump chamber when the same is under relatively low pressure, while preventing reverse flow of liquid from said lowermost pump chamber and for permitting outflow of liquid from the uppermost pump chamber when the same is under relatively high pressure.

The automatic control of such a pumping apparatus is accomplished according to the present invention by providing for automatic operation of the valve means for reversing the connections of the respective gas passage means to the sources of relatively high and relatively low pressure, as soon as each period of operation is complete, or, more specifically, as soon as the chambers of relatively low pressure are all filled with the liquid being pumped, thus insuring the proper length of each period of relatively high pressure and relatively low pressure in the respective chambers and causing a full charge of liquid to be pumped from each high pressure chamber to each low pressure chamber during each period.

With such an arrangement, it is evident that some of the chambers are apt to become filled sooner than some of the other chambers and that when any chamber is filled with liquid the next lower chamber will be substantially emptied of liquid, and a particular object of this invention, as above stated, is to prevent outflow of liquid into the gas passage pipe from a pump chamber which has become filled with liquid and to also prevent loss of the gaseous medium employed for creating the relatively high pressure, through the lower opening of any chamber which becomes emptied of liquid in this manner. For this purpose I provide float valve means operable to prevent outflow of liquid from the

top of any pump chamber into the gas passage means communicating therewith and additional float valve means for preventing outflow of gaseous working medium from the bottom of any pump chamber into the liquid passage leading to the next higher pump chamber. The closing of these float valves not only prevents loss of gaseous working medium, but also controls the time of operation of the automatically controlled reversing valve, in such manner that when the pumping operation in any one period has been completed in all of the stages, the connections to the high and low pressure are reversed.

Float valves of any suitable type may be used for this purpose, but I prefer to use float valves constructed in the novel manner hereinafter described, whereby said valves are kept clean of sand or other material which might tend to clog the same.

While the provision of float valves for the purpose above set forth is of particular advantage in connection with a multi-stage pump, my invention also contemplates the use of such devices with single stage pumps.

The accompanying drawings illustrate embodiments of my invention and referring thereto:

Fig. 1 is a diagrammatic vertical section of a multi-stage pumping apparatus of the type above referred to, with the improvements of the present invention embodied therein.

Fig. 2 is a vertical section of a portion of the pumping apparatus adjacent the partition between two adjacent stages or pump chambers, taken on line 2—2 in Fig. 4, and showing the special valved section and one means of connecting the same to the adjacent standard sections.

Fig. 3 is a vertical section on line 3—3 in Fig. 4.

Figs. 4, 5 and 6 are horizontal sections on lines 4—4, 5—5 and 6—6 in Fig. 2.

Fig. 7 is a vertical section on line 7—7 in Fig. 6.

Fig. 8 is a plan view of the reversing valve and part of the operating means therefor.

Fig. 9 is an elevation of the limit switch for controlling the operation of the reversing valve, taken in the direction indicated by the arrow 9 in Fig. 8.

Fig. 10 is a sectional view of a portion of the pressure responsive circuit closing element of the automatic control means.

Fig. 11 is a diagrammatic view similar to Fig. 1, showing an adaptation of the float valve devices in connection with a single stage pump, for pumping through relatively small heights.

Fig. 12 is a view of the reversing valve means of this form of the invention, in the reverse position to that shown in Fig. 11.

Fig. 13 is a horizontal section of a suitable actual construction of the reversing valve shown diagrammatically in Figs. 11 and 12.

Fig. 14 is a view similar to Fig. 2, showing a different means of connecting the valved section between the adjacent standard sections.

Fig. 15 is a corresponding view, showing the use of this same connecting means in connecting together two adjacent standard sections of the apparatus.

The pumping apparatus comprises essentially an outer casing 1 extending throughout the height thereof and partition means 2 at suitable intervals dividing the space within said casing into a plurality of pump chambers or stages, such as 3*a*, 3*b*, 3*c* and 3*d*, located contiguously one above another, passage means 4 for conducting liquid from the lower portion of each pump chamber to the next higher pump chamber, check valve means 5 located in the respective liquid conducting passages and preferably at or near the bottom thereof and adapted to permit only upward flow of liquid therethrough, and two gas passage means 7 and 8 extending substantially throughout the height of the pump and provided at suitable points with openings placing the respective gas passage means in communication with alternate pump chambers. For example, the gas passage means 7 is shown as communicating with the upper portion of the uppermost stage, or pump chamber 3*d*, the third stage down, and so on throughout the length of the apparatus, while the gas passage means 8 communicates with the second stage and with every alternate stage from there on down. In Fig. 1 the gas passage means 8 is shown as communicating at its lower end with the lowermost pump chamber 3*a*, while the gas passage means 7 is shown as communicating at its lower end with the next higher pump chamber. Beneath the lowermost stage is provided any suitable length of casing 1′ having openings or perforations 11 for inflow of liquid thereto, and liquid conducting passage 4′ may extend down inside said casing and be provided with check valve 5′ at its lower end, so that liquid may be forced up therethrough into the lowermost pump chamber 3*a* during the lower pressure interval therein.

The apparatus is shown as disposed within a well hole 13, such as an oil well, and the perforated casing 1′ extends within the liquid 14 inside said wall, the normal level to which said liquid rises by the natural underground pressure thereon being indicated, for example, at 14′.

In order to obtain maximum utilization of the available space within the well, and provide for the maximum size of working chambers and gas and liquid passages, the liquid passage means 4 and gas passage means 7 and 8 are preferably disposed inside the outer casing 1 so that the pump chambers are pro-

vided by the spaces inside said casing and around and between said passage means.

While in Figs. 1 and 2 the passage means 4, 7 and 8 are shown as arranged substantially in a single plane, this is merely for the purpose of diagrammatic illustration, and in practice it is much more advantageous to arrange the passage means in a triangular relation to one another as shown in the remaining figures of the drawing. It will also be understood that the height of each stage is much greater than represented in proportion to the diameters of the casing and passage means, and this fact is indicated in Fig. 1 by breaking away intermediate portions of each stage. Each stage or pump chamber normally extends throughout a height of several hundred feet and as it is impracticable to use individual sections of such great height, each stage is made up by connecting together a plurality of standard sections, each comprising a section of the outer casing 1 and sections of the several pipes or passage members located inside said casing.

The liquid conducting passage means 4'' leading from the uppermost pump chamber 3*d* may be connected to a pipe 12 for conducting away the liquid delivered therethrough while passage means 7 and 8 may be connected through suitable manually or automatically controlled valve means to sources of relatively high and relatively low pressures, whereby a condition of relatively high pressure and relatively low pressure may be alternately created in the respective gas passages and hence in the pump chamber connected thereto. For this purpose the pipes 7 and 8 may be connected by pipes 15 and 16 respectively to a four-way reversing valve 17 which may comprise, for example, a housing 18 provided with ports 19, 20, 21 and 22 at intervals of 90°, and a rotary valve member 23 provided with passages 24 establishing connection between different pairs of adjacent ports, depending upon the position of said valve member. The pipes 15 and 16 aforesaid may be connected to diametrically opposite ports 19 and 21, while the port 20 is connected by pipe 26 to a source of gaseous working medium at high pressure, such as storage chamber 27 and the remaining port 22 is connected by pipe 28 to a place of relatively low pressure, such as the low pressure storage chamber 29. It will be understood, of course, that the pipe 28 may, if desired, exhaust to the atmosphere, but, inasmuch as I prefer to use natural gas as the working medium for operation of the pump in oil wells, it is more economical to return the same at low pressure to the storage chamber 29, whence it passes through pipe 30 to compressor 31 which delivers it at the necessary high pressure through pipe 32 to the high pressure storage chamber 27. A pipe 33, provided with valve 34, may be connected to the low pressure storage chamber 29, for supplying sufficient gas through said chamber to compressor 31 to provide the necessary supply of gas at high pressure in chamber 27, either before or during operation of the pump. Valves 50, 51 and 52 may also be provided in pipes 28, 32 and 26, for shutting off or controlling the flow of gas through said pipes.

Suitable float valve devices 35 are provided at the points of communication of the pipes 7 and 8 with the upper ends of the respective working chambers, each of said float valve devices being normally open and biased toward open position, as, for example, by the action of gravity, but being operable to closed position when the liquid level in the corresponding pump chambers reaches the level of the valve. Each of these float valve devices may comprise, as shown more particularly in Figs. 3 and 7, a fitting 36 formed as an elbow connected to a flattened or deformed portion 37 of the pipe 7 or 8 (shown as 8 in these figures) and provided at its lower end with a valve port 38 having a conical seat 39, a valve cage depending therefrom and comprising, for example, a plurality of spaced vertical rods 40 and a bottom plate 41, and a float valve 42 disposed within said cage and having a conical valve member 43 which is normally out of engagement with the seat 39 when the float valve is resting on the bottom plate 41 but is adapted to engage said seat when the float valve is lifted due to the liquid in the pump chamber, such as 3*c*, rising about said float valve. Said float valve may be of any suitable type but I prefer to use a valve of the type shown in Fig. 7, comprising a hollow cylindrical body of steel or other metal of such diameter as to move freely up and down within the valve cage and having a sufficient cubical displacement in proportion to its weight to cause it to be lifted by the oil or other liquid being pumped. This cylindrical body is also preferably provided with rifling means, such as spiral ridges (or grooves) 45 on its outer surface, for the purpose of causing twisting or rotary movement of the valve in its seat, as hereinafter described, in case sand or other foreign substance should become lodged between the seat and the valve member and tend to prevent complete closing of the valve.

A float valve device 47 is also provided at the point of communication of each liquid conducting passage 4, as well as the passage 4'', with the lower portion of the corresponding pump chamber, each of said float valve devices comprising a valve member 42', biased, as by the action of gravity, toward position to close port 38', but being normally held open so long as the corresponding pump chamber is filled with liquid above the level of said float device. These latter float devices 47 are substantially the same as the float valve

devices 35 above described but are connected in inverted position, as shown in Fig. 3.

It should be understood that the invention is not restricted to the use of float valves of the particular type above described. The valve members themselves, instead of being hollow steel or metal members, may be solid members of lighter material, such as wood, or of any other type, and said valve members may be formed and mounted in any suitable manner, so as to shut off the respective openings controlled thereby upon complete filling, or complete emptying, of any pump chamber.

An advantageous means of providing the partitions 2 between the several pump chambers and the float valve and check valve means adjacent thereto, is illustrated in Figs. 2 to 7, which show these elements between the uppermost pump chamber 3*d* and the next lower pump chamber 3*c*, it being understood that a similar arrangement is provided between each pair of adjacent pump chambers. A short casing section 55 is shown as connected between the casings 1 of the pump chambers or stages, the partition 2 being mounted intermediate the height of said casing section 55. Said casing section is shown as provided with end walls 56 at the top and bottom thereof, connected by deformed or flattened sections of tubing or pipe for providing connections between the pipes 4, 7 and 8 of the adjoining stages, these deformed sections including the member 37 above mentioned for connecting the pipe 8, a similar member 57 for connecting the pipe 7, and a member 58 for connecting in this particular case the pipe 4 to the pipe 4″. These three members are disposed in triangular relation as shown in Fig. 5 corresponding to the triangular relation of the members 4″ (or 4), 7 and 8, as shown in Fig. 4, but are flattened at their inner sides, so as to provide a space therebetween within which are mounted, as shown, the float valve devices 35 and 47 aforesaid. The check valve 5 for preventing downflow of liquid in the liquid conducting pipes 4, 4′ and 4″ may also be mounted in this special connecting section, each of such check valves comprising, for example, a ball or other valve member mounted within the pipe section 58 and cooperating with a valve seat 59 and retained by suitable cage means such as pins 60.

The casing members 1 of adjacent standard sections are provided with end walls 62 to which the casing members and the internal pipes 4, 7 and 8 are tightly connected as by being welded thereto. The special valved connecting section is connected between the adjacent stages by means of coupling collars 63, while gaskets 64 are provided for causing a tight fit therebetween. The end walls 56 and 62 as well as gaskets 64 are provided with aligned openings 66 for establishing communication between the pump chamber 3*c* and the chamber 67 below the partition 2 and between pump chamber 3*d* and the chamber 68 above said partition, whereby said chambers 67 and 68 constitute in effect continuations of the chambers 3*c* and 3*d* respectively.

All of the standard sections, throughout the height of the pump, may be provided at their ends with similar end walls welded to the outer casing and inner pipes, and may be connected together by similar coupling means to those above described.

A modified construction of the adjacent ends of the standard sections, and of the special valved connecting sections and modified means of coupling said sections together, is illustrated in Figs. 14 and 15. In Fig. 14 the valve connecting section is of substantially the same construction as shown in Figs. 2 and 3 with the exception of the upper and lower ends of the outer casing section 55 and the deformed interval sections 37, 57 and 58. The upper end of the outer casing section 55 is externally threaded as shown at 70, while the upper ends of the inner sections 37, 57 and 58 are reduced as shown at 71, 72 and 73 respectively to an external diameter substantially equal to the internal diameter of the corresponding pipes of the adjacent standard section. The lower portions 74, 75 and 76 of the respective internal pipe sections 37, 57 and 58 are of substantially the same internal diameter as the corresponding pipes in the standard sections, and are each provided with packing glands 77 threaded thereon and packing means 78. The lower ends of the corresponding internal pipes of the standard sections are also provided with similar packing glands 79 and packing means 80. The lower end of the outer casing section 55 is provided with an external shoulder 82, and is provided with a coupling member 83 internally threaded at its lower end as at 84 and having an internal shoulder 85 at its upper end, suitable gasket means 86 being provided between the shoulders 82 and 85. The upper end of the external pipe 1 of each standard section is externally threaded as at 87 to receive the coupling member, while the upper ends of the internal pipes 4, 7 and 8 of each standard section are reduced as shown at 89, 90 and 91 respectively to an external diameter substantially equal to the internal diameter of the corresponding pipes in the adjacent standard section or in the special valved section as the case may be.

In connecting the special valved section to the upper end of the adjacent standard section, the coupling member 83 is raised so as to permit access to the lower ends of the several internal pipes, and said internal pipes are then lowered over the reduced upper ends 89, 90 and 91 of the corresponding standard pipe sections, and the packing glands 77 are then tightened sufficiently to maintain substantially fluid tight fits between these pipes. The coupling member 83 is then low-

ered and screwed onto the outer casing section 1. When the parts thus coupled together are suspended in the well, the weight of the outer casing will compress the gasket means 86 tightly between shoulders 82 and 85, so as to maintain a tight joint at this point. The packing means 78 permit slight relative sliding movement of the adjacent sections of internal pipes inside one another to accommodate slight relative displacement of the outer casing sections during the firm seat of shoulder 85 on shoulder 82, and also permit slight sliding movement of said internal pipes due to expansion or contraction thereof upon variation in temperature or for any other reason, and thus prevent loosening of the joints such as might occur if these internal pipes were rigidly connected together. This ability of the internal pipe sections to slide inside one another also prevents buckling thereof.

The lower end of the external casing 1 of each standard section may be provided with an external shoulder 95 and an internally threaded coupling member 96. In connecting the next higher standard section to the special valved section, the external casing 1 is first raised slightly above the lower ends of the internal pipes, for example to the position shown in dotted lines at 97, and the internal pipes are coupled together in the same manner as above described. The external casing is then lowered into position of engagement with the upper end of casing section 55, suitable gasket means 98 being provided therebetween, and the coupling member 96 is then tightened, so as to couple the outer casings together. As indicated in Fig. 15 the several standard sections of outer casing and internal pipes are connected to one another in substantially the same manner as just described.

For operating the reversing valve 23, so as to reverse the conditions of relatively high and relatively low pressure in the alternate pump chambers, the shaft 101 of the rotary valve member 23 may be provided with a worm wheel 102 operated by a worm 103 on the shaft 104 of an electric motor 105. One of the wires, such as 106 of the operating circuit of motor 105, leads to any suitable source of power supply while the other wire 107 leads to one contact of a relay switch 108, the other contact of which is connected by wire 109 to the other side of the power supply. The electromagnet controlling said switch is indicated at 110, said switch being biased toward open position by means of spring 111. One side of electromagnet 110 is connected by wire 112 to a suitable source of power supply while the other side is connected by wire 113 to the fixed contact 114 of a differential pressure controlled switch 115, which may be constructed as shown particularly in Fig. 10. Said switch is provided with a flexible diaphragm 116 dividing the interior thereof into two chambers 117 and 118 which are connected by pipes 119 and 120 to the high and low pressure points respectively of a Venturi tube 121. The diaphragm 116 is biased as by its own resilience, into position of engagement with a contact member 114. Said contact member 114 is insulated from the case of switch 115 as by an insulating sleeve 122.

The metal diaphragm 116 serves as the other contact member of the switch and the control circuit is completed through the metal casing of the switch and through pipes 119 and 120 to pipe 28 and thence through return wire 123.

A limit switch is also provided comprising a metal disc 124 mounted on the shaft 101 of reversing valve 23 and provided with four segments 125 of insulating material, spaced 90° apart, so as to provide for rotation of the valve through one quarter turn each time the electric motor is set in operation. The limit switch further comprises a fixed contact arm 126 engaging disc 124 and insulating segments 125, said contact arm being contacted by wire 127 and wire 113 aforesaid to the electromagnet 110. The contact disc 124 is electrically connected through shaft 101 and valve 23 to the pipe 28, so that wire 123 serves as a return wire for the limit switch as well as for the differential pressure switch 115.

In the operation of the above described apparatus, with the reversing valve in the position shown in Fig. 1, a condition of low pressure will be maintained in chambers 3*a* and 3*c* and a condition of high pressure will be maintained in chambers 3*b* and 3*d*. Under these conditions, liquid will be forced, by the hydrostatic pressure in the well, into the lowermost chamber 3*a*, while liquid will simultaneously be forced from chamber 3*b* to chamber 3*c*, and from chamber 3*d* out through the delivery pipe 12. During this stage of the operation, gas is forced under relatively high pressure from chamber 27 through pipe 26, one of the valve passages 24, pipe 15, pipe 7, and the open float valves 35 thereof, into chambers 3*b* and 3*d*, while gas at relatively low pressure will be displaced from chambers 3*a* and 3*c* through the open float valves 35, at the upper ends of these chambers, pipes 8 and 16, and the other valve passages 24, and pipe 28, to the low pressure chamber 29, the compressor 31 serving to maintain the necessary pressure in chamber 27 to cause this movement of the gaseous working medium.

When any one of the pump chambers which are at that time under low pressure, that is the chambers 3*a* and 3*c* in the above example, becomes substantially filled with liquid, the float valve device 35 at the upper end of said chamber will be closed, due to the liquid rising around the valve member 42 and raising the same into position to close port 38. Outflow of liquid from this pump chamber into the pipe 8 is thus prevented.

Furthermore, when any pump chamber which is at that time under high pressure, that is, either the chamber 3*b* or 3*d* of the above example, becomes substantially emptied of liquid, the float valve device 47 at the lower end of said chamber will be closed due to the liquid falling below the valve member 42′ thereof and permitting said valve member to fall in position to close port 38′. This prevents escape of gaseous working medium from said chamber into the liquid conducting pipe 4.

It may be pointed out, in connection with the operation of the float valve devices, that the flow of liquid or gas therethrough will act upon the rifling means above described and tend to cause the same to rotate while moving to or from their seats, and such rotation will assist materially in keeping these seats clean and free from sand or other foreign material which might interfere with tight closure of said valves.

When the transfer of liquid from each high pressure stage to the next higher low pressure stage, as well as the inflow of liquid into the lowermost stage, is completed, all of the float valve devices 35 connected to pipe 8 will be closed in the manner above described, so that the outflow of gas through pipe 8 and the other passages above described to the low pressure chamber will cease. The connection of Venturi tube 121 to the control switch 115 is such that so long as an appreciable flow of gas through pipe 28 is maintained, that is so long as gas continues to be displaced from any of the low pressure pump chambers, the differential pressure created by said Venturi tube will be sufficient to hold diaphragm 116 out of contact with contact member 114. However, upon cessation of gas flow through said pipe, said differential pressure falls to approximately zero, allowing said diaphragm to be forced by its own resilience into contact with member 114 so as to close the circuit at the pressure controlled switch 115 and hence energize electromagnet 110. This in turn causes relay switch 108 to close and complete the operating circuit of motor 105. Said motor will thereupon cause rotation of rotary valve member 23 through one quarter turn so as to bring the passages 24 in position to reverse the direction of gas flow, by connecting the pipe 16 to pipe 26, and the pipe 15 to pipe 28.

It will be seen that as soon as the rotary valve member is moved slightly from its initial position of rest, the insulating segment 125 upon which contact arm 126 was then resting will be moved out of engagement therewith so as to bring the contact disc 124 into contact with arm 126, thus completing an energizing circuit for relay magnet 110 independent from the differential pressure switch 115. As soon as the valve member reaches a position where the passages 24 just begin to uncover the ports corresponding to their new position, flow of gas therethrough will commence immediately, which will again produce a sufficient pressure difference in the Venturi tube to open switch 115. The limit switch consisting of disc 124 and arm 126 will, however, remain closed and cause the motor to continue operation until the valve is rotated sufficiently to bring the passages 24 into substantially complete register with the ports controlled thereby, when another insulating segment 125 will be brought into position beneath contact arm 126 and break the electrical connection at this point, thus causing the relay switch to open and stop motor 105. The valve 23 will then occupy a position, such that one of the passages 24 connects pipe 16 to pipe 26 while the other passage connects pipe 15 to pipe 28. Chambers 3*b* and 3*d* will, therefore, be connected to the low pressure storage chamber and chambers 3*a* and 3*c* to the high pressure storage chambers, so that liquid will be displaced from the latter chambers to the former. This stage of the operation will continue until the displacement of liquid is complete, the float valve devices 47 and 35 serving as before to respectively prevent outflow of gaseous working medium from the high pressure chambers into the liquid conducting pipe 4 and overflow of liquid from the low pressure chambers into the pipe 7. When the low pressure chambers are all again filled with liquid, the flow of gas to the low pressure storage chamber will cease and the differential pressure valve 115 will operate as before to start the electric motor and operate reversing valve 23 through another quarter turn, thus restoring the entire system to its initial condition, and the operation will then again proceed as before.

It will be understood that a single compressor, with its high and low pressure storage chambers, may be used to furnish the working medium for a plurality of pumps in different wells adjacent thereto. For example, in Fig. 1 I have shown a second pipe 26′, provided with valve 52′, leading from the high pressure chamber 27, and a second pipe 28′, provided with valve 50′, leading to the low pressure chamber 29, and these pipes may be connected through reversing valve means in the same manner as above directed, to a similar pumping apparatus in another well.

The apparatus illustrated in Figs. 11, 12 and 13 shows a single stage pump operated by gas pressure and provided with automatic reversing means according to my invention for causing automatic reversal from high pressure to low pressure or vice versa, in the pump chamber, each time said pump chamber becomes completely filled or completely emptied of liquid.

This apparatus comprises a casing 131 hav-

ing a perforated portion 131′ at the lower end thereof, and two horizontal partitions 132 between which is provided the pump chamber 133, a liquid conducting pipe 134 extends up from a point within the perforated section 131′ through the pump chamber 133 and through the upper partition 132 into a delivery chamber 135, from the upper end of which liquid is conducted away by pipe 136. Pipe 133 communicates with pump chamber 133 adjacent the bottom thereof through an elbow 137 and a float valve device 138 which may be similar to the float valve device 47 above described. An upwardly opening check valve 139 is provided at the bottom of the liquid conducting pipe 134 and a similar check valve 140 is provided in said pipe directly above the point of connection of elbow 137.

A pipe 142 extends through the top 143 of casing 131 and through the upper partition 132 and opens at its lower end through float valve device 144 into the upper end of pump chamber 133. The float valve device 144 may be of the same construction as the device 35 above described. The upper end of pipe 142 is connected by pipe 145 to suitable reversing valve means indicated at 146 which are adapted to alternately place the pipe 145 in connection with a pipe 147 leading to a suitable point of relatively low pressure and a pipe 148 leading to a point of relatively high pressure, said pipes leading, for example, to low pressure and high pressure storage chambers, such as the chambers 29 and 27 above described. Said reversing valve means is shown diagrammatically in Figs. 11 and 12 as comprising two separate units one of which comprises housing 149*a* and rotary valve member 150*a* and the other of which comprises housing 149*b* and rotary valve member 150*b*. The pipe 145 aforesaid is connected to one port of housing 149*a* while the diametrically opposite port is connected by pipe 153 to one of the ports of housing 149*b*. The remaining ports of housing 149*a* are connected together by pipe 154, in which is connected a Venturi tube 155 connected to a differential pressure switch 156 similar to the switch 115 above described and adapted to control the operation of the valve means in the same manner. The two remaining ports of housing 149*b*, which are located diametrically opposite one another and 90° from the first named port of said housing, are connected to the pipes 147 and 148 aforesaid. The rotary valve member 149*a* is provided with passages 158 and 159, while the rotary valve member 150*b* is provided with passages 161 and 162.

In actual practice the two units of valve 146 may be combined in the single housing 149 and a single rotary valve member 150, as shown in Fig. 13, the passage 153′ taking the place of pipe 153 above described and the remaining connections being substantially as shown in the diagrammatic view. The shaft 164 of rotary valve member 150 is shown as provided with a worm wheel 165, through which the same may be operatively connected to a motor for effecting a one-quarter turn motion thereof each time said motor is set in operation, in substantially the same manner as above described.

With the parts of the reversing valve in the position shown in Fig. 11, pump chamber 133 is connected through pipes 142 and 145, passage 158, pipe 154, passage 159, pipe 153, (or passage 153′), passage 161 and pipe 147 to the low pressure storage chamber, so that a condition of relatively low pressure prevails in said pump chamber, and liquid from the well is caused by the hydrostatic pressure therein to enter through check valve 139 and through the lower portion of pipe 154 and float valve 138, into said pump chamber. The gaseous medium displaced from said pump chamber by said liquid passes through the pipes and passages above described to the low pressure storage chamber. Check valve 140 is at this time closed, so as to prevent return of liquid from delivery chamber 135 into the pump chamber.

When pump chamber 133 becomes substantially filled with liquid, the float valve device 144 will close, thus stopping the outflow of gas, and due to the resulting lack of pressure difference in the Venturi tube 155, the switch 156 will operate in the same manner as the switch 115 above described, to start operation of the operating motor for the reversing valve and to cause the same to move the valve ports to the positions shown in Fig. 12, it being understood that suitable limit switch means, such as above described, may be provided to cause the operating motor to stop when the valve passages are in complete register with the proper ports.

With the valve in this new position, gaseous medium under relatively high pressure passes from the high pressure storage chamber through pipe 148, passage 161, pipe 153, (or passage 153′) pipe 154, passage 159, pipes 145 and 142 into pump chamber 133, the pressure of said gaseous working medium being sufficient to open float valve 144. The liquid will, therefore, be displaced from the pump chamber through float valve 138, elbow 137, check valve 140 and the upper portion of pipe 134 into delivery chamber 135 and thence out through the delivery pipe 136. The lower check valve 139 will be closed during this period so as to prevent return of liquid from the pump chamber into the well. When the liquid in pump chamber 133 falls below the level of the float valve device 138, said valve will close, thus preventing outflow of gaseous medium therethrough and also causing the differential pressure switch 156 to again operate to cause a further quarter turn motion

of the valve and again place the pump chamber in communication with the low pressure storage chamber, whereupon the cycle of operations will be repeated.

I claim:

1. A liquid pumping apparatus comprising a series of superposed pump chambers, liquid conducting passage means connecting the lower portion of each pump chamber to the next higher pump chamber, check valve means in each of said liquid conducting passage means for preventing downflow of liquid therethrough, means for delivering gas to alternate pump chambers to create relatively high pressure therein and means for removing gas from the remaining pump chambers to create relatively low pressure therein so as to cause displacement of liquid from each high pressure chamber through a corresponding passage means to the next higher low pressure chamber, valve means for reversing the connections of said pump chambers to said gas delivering and gas removing means so as to change the conditions in the respective pump chambers from relatively high pressure to relatively low pressure and vice versa, float valve means for shutting off communication from each high pressure pump chamber to the corresponding passage means upon substantially complete displacement of liquid from that particular chamber, and means for automatically operating said reversing valve means upon substantial cessation of liquid displacement through the passage means leading from all of said high pressure chambers.

2. A liquid pumping apparatus comprising a series of superposed pump chambers, liquid conducting passage means connecting the lower portion of each pump chamber to the next higher pump chamber and provided with check valve means for preventing downflow of liquid therethrough, means for delivering gas to alternate pump chambers to create relatively high pressure therein and means for removing gas from the remaining pump chambers to create relatively low pressure therein, so as to cause liquid to be displaced from each high pressure chamber through a corresponding passage means to the next higher low pressure chamber, valve means for reversing the connections of said pump chambers to said gas delivering and gas removing means so as to change the conditions in the respective pump chambers from relatively high pressure to relatively low pressure and vice versa, float valve means for shutting off communication from each low pressure pump chamber to said gas removing means upon substantially complete filling of that particular pump chamber with liquid, and means for automatically operating said reversing valve means upon substantial cessation of gas flow from all of said low pressure pump chambers to said gas removing means.

3. A liquid pumping apparatus comprising a series of superposed pump chambers, passage means for conducting liquid from the lower portion of each pump chamber to the lower portion of the next higher pump chamber, and provided with check valve means for preventing downflow of liquid therethrough, two gas passage means extending throughout the major portion of the height of said series of pump chambers and communicating respectively with alternate chambers, means for creating conditions of relatively high pressure and relatively low pressure in the respective gas passage means and for periodically reversing the conditions of relatively high and relatively low pressure in the respective gas passage means, float valve means for shutting off communication from each pump chamber to the gas passage means connected thereto upon substantially complete filling of said pump chamber with liquid, and means operable upon substantial cessation of gas flow through the low pressure passage means due to closing of said float valves in all of the pump chambers communicating therewith, to automatically reverse the conditions of relatively high and relatively low pressure in the respective gas passage means.

4. A liquid pumping apparatus comprising a series of superposed pump chambers, passages for conducting liquid from the lower portion of each pump chamber to the lower portion of the next higher pump chamber and provided with check valves permitting only upflow of liquid therethrough, two gas passages extending throughout the major portion of the height of said series of pump chambers and communicating respectively with alternate chambers, means for supplying gaseous medium at relatively high pressure, means for removing gaseous medium at relatively low pressure, valve means adapted to establish communication between one of said gas passages and said gaseous medium supplying means and between the other of said gas passages and said gaseous medium removing means so as to effect displacement of liquid from each chamber connected to the high pressure gas passage to the next higher chamber, means for periodically operating said valve means to reverse the communications between the gas passages and the gaseous medium supplying and removing means, means operable upon substantially complete displacement of liquid from any chamber connected to the high pressure gas passage to close the liquid conducting passage leading from said chamber to the next higher chamber, and means controlled by flow of gaseous medium through one of said gas passages and adapted to cause operation of said valve operating means upon substantial

cessation of flow of gaseous medium through said last named passage due to closing of all of said liquid conducting passages.

5. A liquid pumping apparatus comprising a series of superposed pump chambers, passages for conducting liquid from the lower portion of each pump chamber to the lower portion of the next higher pump chamber and provided with check valves permitting only upflow of liquid therethrough, two gas passages extending throughout the major portion of the height of said series of pump chambers and communicating respectively with alternate chambers, means for supplying gaseous medium at relatively high pressure, means for removing gaseous medium at relatively low pressure, valve means adapted to establish communication between one of said gas passages and said gaseous medium supplying means and between the other of said gas passages and said gaseous medium removing means so as to effect displacement of liquid from each chamber connected to the high pressure gas passage to the next higher chamber, means for periodically operating said valve means to reverse the communications between the gas passages and the gaseous medium supplying and removing means, means operable upon substantially complete filling with liquid of any chamber connected to the low pressure gas passage to close communication from said chamber to said passage, and means controlled by flow of gaseous medium through one of said gas passages and adapted to cause operation of said valve operating means upon substantial cessation of flow of gaseous medium through said last named passage due to closing of communication from said low pressure gas passage to all of the chambers connected thereto.

6. In a liquid pumping apparatus, a pump chamber, liquid conducting passage means communicating with the lower portion of said pump chamber and extending from below the lower end of said pump chamber to above the upper end thereof, check valve means in said liquid conducting passage means adapted to permit only upflow of liquid from below said pump chamber to said chamber when the pressure in said chamber is less than the pressure below the same and upflow of liquid from said pump chamber to above the same when the pressure in said pump chamber exceeds the pressure above the same, means for supplying gaseous medium at relatively high pressure, means for removing gaseous medium at relatively low pressure, means controlling communication between said pump chamber and said gaseous medium supplying and removing means, means operable upon substantially complete filling of said pump chamber with liquid to operate said communication controlling means to place said pump chamber in communication with said gaseous medium supplying means, and means operable upon substantially complete displacement of liquid from said pump chamber to operate said communication controlling means to place said pump chamber in communication with said gaseous medium removing means.

In testimony whereof I have hereunto subscribed my name this 18th day of January, 1929.

EDSON R. WOLCOTT.