June 24, 1930. C. H. HARDIE ET AL. 1,766,382

MULTISTAGE AND EXPANSION FLUID PUMP

Filed March 5, 1929 3 Sheets-Sheet 1

FIG. 1.

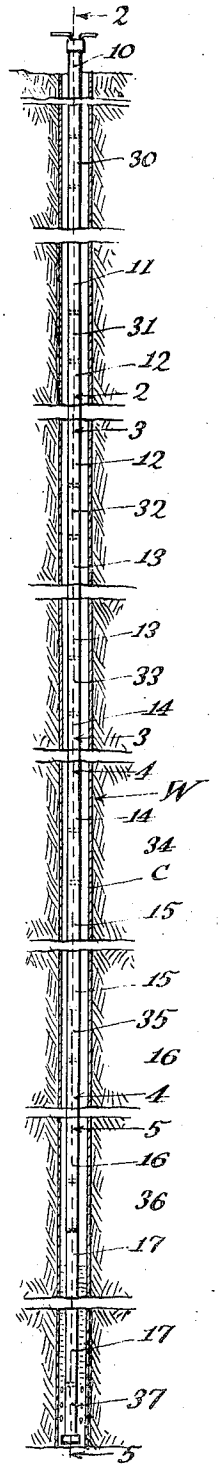
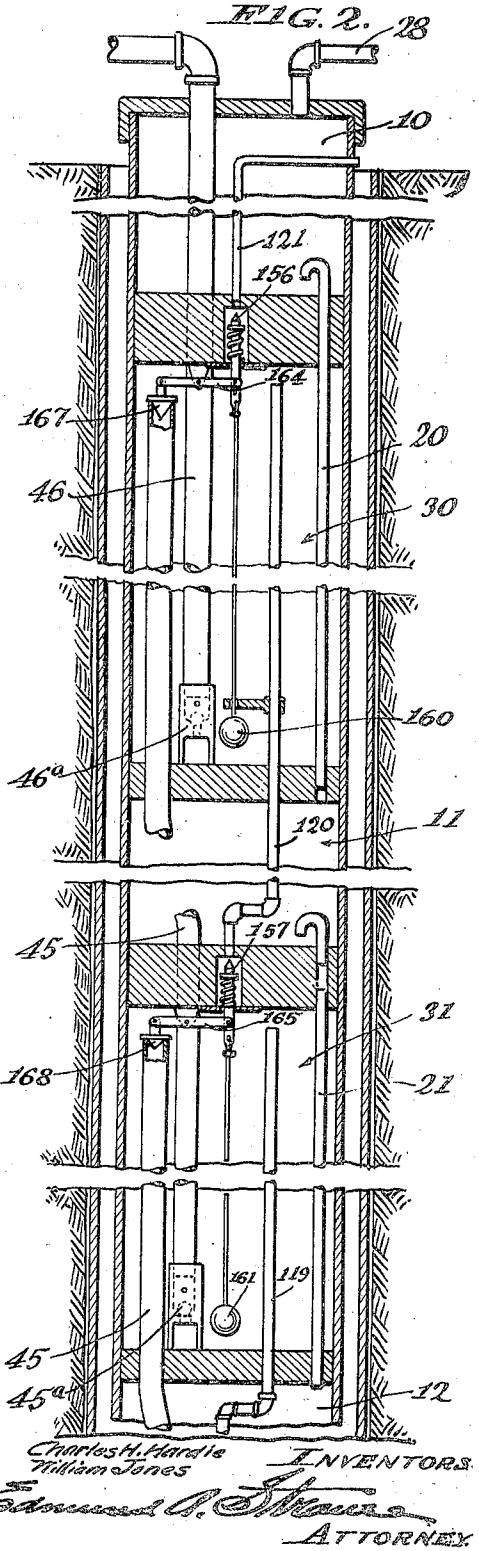


FIG. 2.



Charles H. Hardie
William Jones
INVENTORS

Edmund A. Stevens
ATTORNEY.

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FIG. 4.

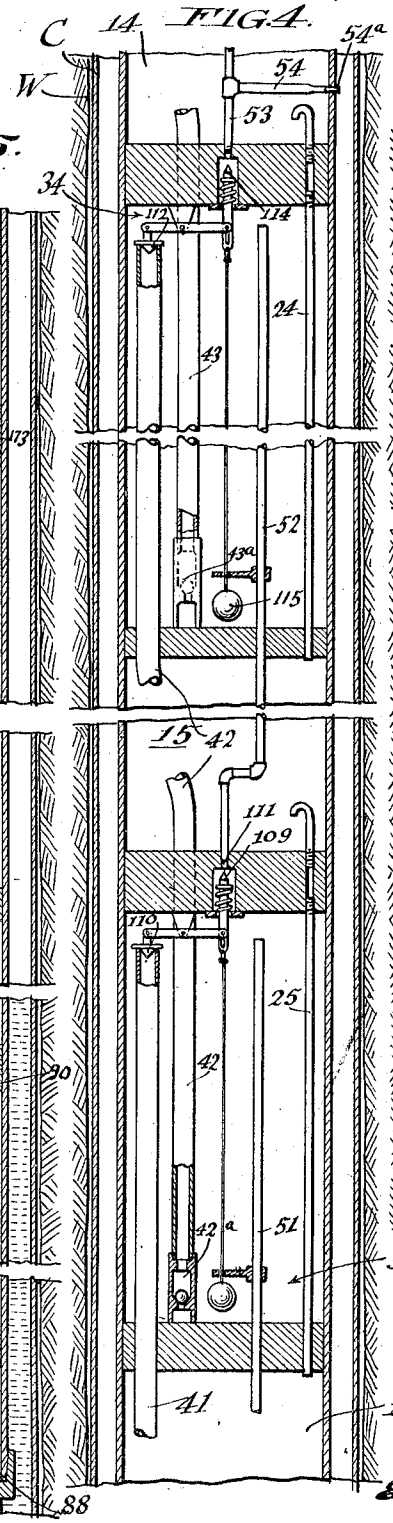


FIG. 5.

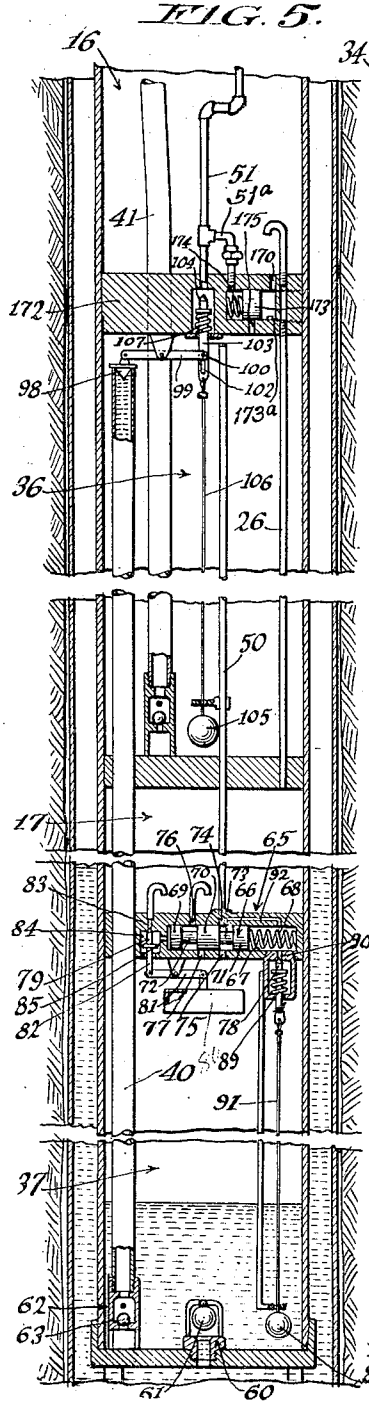
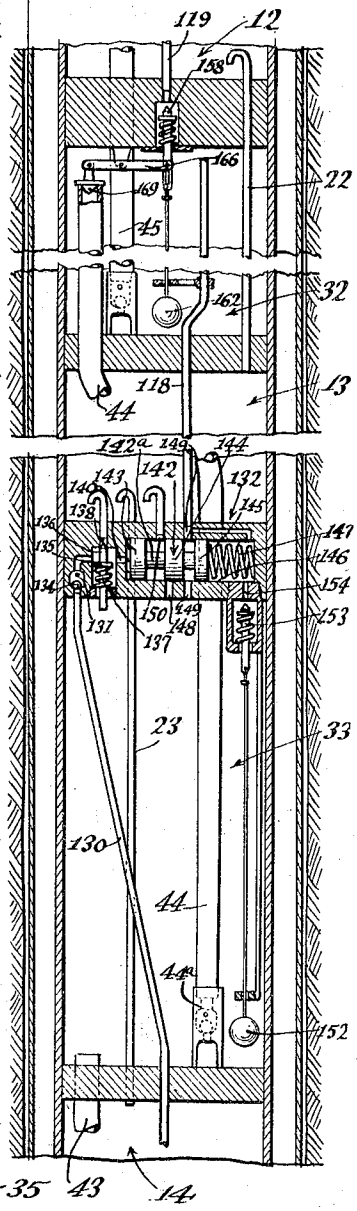


FIG 3.



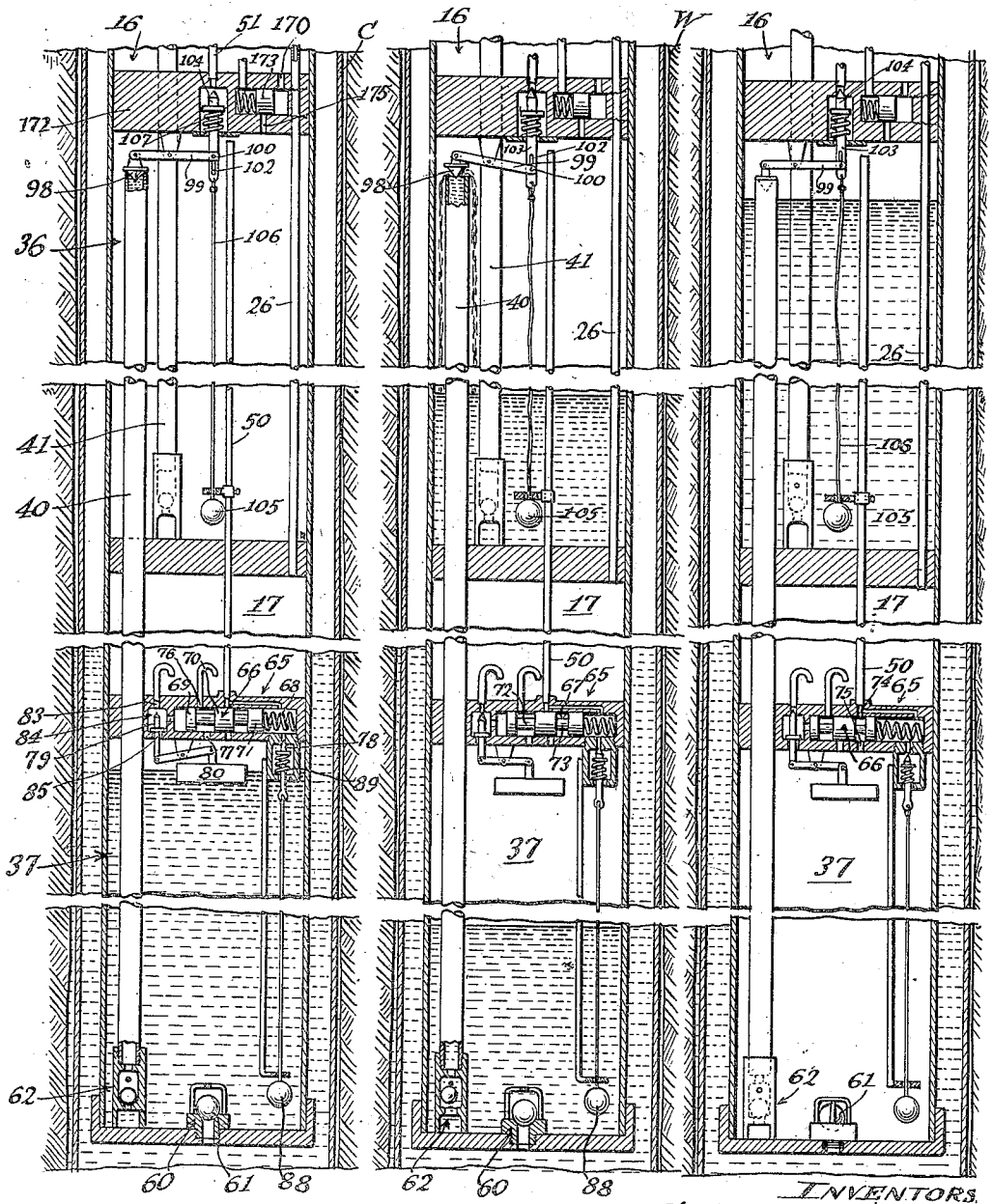
INVENTORS
Charles H. Hardie
William Jones
Edmund A. Thomas
ATTORNEY.

June 24, 1930. C. H. HARDIE ET AL 1,766,382

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FIG. 6. FIG. 7. FIG. 8.



INVENTORS.
Charles H. Hardie
William Jones
Edmund Stevens.
ATTORNEYS

Patented June 24, 1930 1,766,382

UNITED STATES PATENT OFFICE

CHARLES H. HARDIE, OF SOUTH GATE, AND WILLIAM JONES, OF LOS ANGELES, CALIFORNIA

MULTISTAGE AND EXPANSION FLUID PUMP

Application filed March 5, 1929. Serial No. 344,392.

The principal object of this invention is to provide a fluid lift which will elevate fluid from the bottom to the top of a well by successive expansions of compressed air in direct contact with the fluid.

Another object of this invention is to provide a pump or fluid lift operated by compressed air or casing head gas under pressure adapted to elevate fluid from one chamber to the one above it by expansion of the compressed air or gas, the number of expansions being determined by the pressure of the compressed air, each successive expansion lifting a column of fluid upward, the force of expansion generally being employed to exert pressure on decreasing elevation at each expansion, such as is in compound or triple expansion steam engines is converted into longitudinal expansions.

Still another object of the invention is to provide a fluid lift that is free from reciprocating parts ordinarily employed in pumping mechanisms, such as sucker rods, jacks, working barrels, and the like.

A further object is to provide a fluid lift which will operate in wells which are of great depth or in which the bore is irregular in formation.

Referring to the drawings in which a single embodiment of the invention is illustrated by way of example:

Fig. 1 is a view showing the fluid lift installed in a well.

Fig. 2 is a sectional view of the upper portion of the fluid lift taken on line 2—2 of Fig. 1.

Fig. 3 is a sectional view showing an intermediate portion of the fluid lift taken on line 3—3 of Fig. 1.

Fig. 4 is a sectional view similar to Figs. 2 and 3 taken on line 4—4 of Fig. 1.

Fig. 5 is a sectional view showing the lower end of the fluid lift taken on line 5—5 of Fig. 1.

Fig. 6 is a sectional view similar to Fig. 5 showing the position of the fluid control valves when fluid first enters the fluid lift.

Fig. 7 is a view similar to Fig. 6 showing fluid being transferred or lifted from one lifting chamber to the one above it.

Fig. 8 is a view showing the position of the fluid control valves immediately after the second lifting chamber has been filled with fluid.

The fluid lift consists primarily of a plurality of high pressure air or gas chambers interposed between a plurality of lifting chambers. Compressed air or casing head gas is introduced into the uppermost high pressure chamber and is conducted to each of the succeeding high pressure chambers through conduits passing through the lifting chambers.

Starting with the uppermost, the high pressure chambers are designated at 10, 11, 12, 13, 14, 15, 16, and 17, and are connected so that air may pass from one chamber to the next by pipes or conduits 20, 21, 22, 23, 24, 25, and 26, compressed air or gas under pressure being introduced into the high pressure chamber 10 through a pipe 28. The lifting chambers are designated at 30, 31, 32, 33, 34, 35, 36, and 37, and are connected by pipe lines 40, 41, 42, 43, 44, and 45, in order to allow fluid to be transferred or lifted from one fluid chamber to the one above it and finally discharged through a pipe line 46 in the chamber 30 to storage.

As illustrated the fluid lift is shown more or less diagrammatically so far as assembling details are concerned, such as couplings, unions, etc., it being understood that suitable fittings may be employed so that the fluid lift may be assembled in sections and lowered into the well —W— within the casing —C—. Fluid enters the lowermost lifting chamber and is forced therefrom into the succeeding lifting chambers by expansion of compressed air. The rising column of fluid and the admission of compressed air to effect it is controlled by a system of valves and floats more fully described in detail as follows:

Referring now to Figs. 3, 4, and 5, the fluid lift is submerged below the fluid level so that fluid will fill the chamber 37 by gravity. Fluid enters the chamber 37 through the check valve 60 lifting the ball 61 off its seat, at the same time fluid enters the pipe 40 through check valve 62 lifting the ball 63, and continues to fill the chamber 37 and

rise in the pipe 40 until the level of fluid in pipe 40 is equal to the fluid in chamber 37.

During the above stated interval air above the fluid in the chamber is allowed to escape to atmosphere through the vent pipes 50, 51, 52, 53, and 54. A plate or head 65 forms a division between the lifting chamber 37 and high pressure chamber 17 and is also utilized to carry a balanced piston valve 66 which is slidable in a bore 67 and urged forward by an expansion spring 68. The piston valve consists of three pistons 69, 70, and 71, which are connected by two reduced portions 72 and 73, and normally lies in the position shown in Fig. 5 at which time vent ports 74 and 75 are opened and high pressure air ports 76 and 77 are closed.

The piston valve serves to open and close the ports 74, 75, 76, and 77 at proper intervals and is actuated by opening and closing needle valves 78 and 79 respectively. The needle valve 79 is operated by a float 80 which is connected to one end of a pivotedly mounted lever 81 the other end of which is connected to the stem 82 of the needle valve 79. Normally the needle valve 79 closes a port 83 leading from the valve cage 84 in the plate 65 to the high pressure chamber 17. The port 83 remains closed until fluid entering the chamber 37 reaches the float 80 and lifts same which in turn through the lever will move the needle valve 79 down, opening the port 83 and admitting high pressure air into the valve cage 84 thence to the end of the bore 67 through a port 85. High pressure air from the chamber 17 will then act on the piston 69 of the piston valve 66 and move the piston valve to the position shown in Fig. 6 which will open the ports 76 and 77 and allow high pressure air from the chamber 17 to enter the chamber 37. In order to return the piston valve to normal position the needle valve 78 is actuated by means of a float 88 which is of sufficient weight to pull the valve from its seat against the action of a spring 89 (when the chamber 37 is empty) and open a port 90 entering the bore 67, thus equalizing air pressure on both ends of valve, the float 88 being connected to the valve 78 by a cable 91.

When the fluid lift is first installed and no high pressure air is introduced, fluid will enter the chamber 37 by gravity, air above the fluid will have a clean vent to atmosphere and will lift the float 80 which in turn will cause the needle valve 79 to open ports 83 and 85. High pressure air is then admitted through the pipe 28 and will charge all of the high pressure chambers 11, 12, 13, 14, 15, 16, and 17, the pressure in the high pressure chambers continuing to increase until sufficient pressure is developed to overcome the resistance of the spring 68 at which time the piston 66 will be moved to the position shown in Fig. 6 by high pressure air from the chamber 17 entering the bore 67 through the ports 83 and 85. It will be noted that when the lifting chamber 37 is filled with fluid the needle valve 78 closes the port 90, hence a bleeder port 92 serves to vent any air in bore 67 back of the piston 71 of the piston valve when it is being moved over.

At the moment the piston valve is moved to the position shown in Fig. 6 high pressure air from the chamber 17 will enter the lifting chamber 37 through the ports 76 and 77 passing around the reduced portion 72 of the piston valve and exert sufficient pressure on the fluid in the chamber to cause it to be transferred into the lifting chamber 36 through the pipe 40 at which time the ball of the check valve 60 will be seated and the ball 63 of the check valve 62 unseated, the rising column of fluid will lift a valve 98 seated in the upper end of the pipe 40 as shown in Fig. 7.

The valve 98 is connected to one end of a pivoted lever 99, the other end of the lever having a pin 100 slidable in a slot 102 in the stem 103 of a needle valve 104 which is normally pulled downward by the weight of a float 105 connected to the valve stem by a cord 106 against the action of a spring 107 when the chamber 36 is empty as shown in Figs. 5 and 6. During the interval when the chamber 36 is being filled, the valve 104 remains unseated due to the tilted position of the lever which will carry the pin 100 to the lower end of the slot 102 and prevents upward movement of the valve stem due to the action of the spring 107, thus allowing air above the fluid in the chamber to pass through the vent pipes 51, 52, 53, and 54 to atmosphere.

As the fluid in the chamber recedes due to the high pressure air entering fluid chamber through the ports 76 and 77 from the high pressure air chamber 17 and forcing the fluid in the pipe 40 upward into the chamber 36 the float 80 will first return to normal position and close the port 83 cutting off high pressure air to the piston 66, which will remain in the position shown in Figs. 6 and 7 allowing high pressure air from the chamber to continue to expel the fluid in the chamber 37 into the chamber 36 through the pipe 40 until the chamber 36 is empty, at which time the weight of the float valve 88 will open the port 90 and allow the compressed air in the chamber 37 plus the action of the spring 88 to return the piston 66 to its former position as shown in Fig. 5, thus cutting off high pressure air from the chamber 17, it being noted that the check valve 61 is closed due to high pressure air in the chamber 37.

From the foregoing it will be seen that during the transferring of fluid from the chamber 37 to 36 the chamber 37 is charged with compressed air from the high pressure chamber 17 and finally cut off or closed to additional compressed air from the chamber 17

or fluid when all the fluid in it has been transferred to the chamber 36 from the chamber 37. The remaining air entrapped in the chamber 37 is compressed and therefore capable of expansion. At the moment the float valve 88 drops and opens the port 90 the expansion of the air in the chamber 37 will exert a pressure on the fluid in the chamber 36 through the pipe 50 (ports 74 and 75 then being open) and force the fluid from the chamber 36 into the chamber 35 through pipe 41 which will lift a valve 110 similar to the valve 98 and fill the chamber 35 in a like manner to the chamber 36.

During the filling of the chamber 35, needle valve 109 of the same construction and operation as the needle valve 104 will open a port 111 allowing air above the fluid in the chamber 35 to be vented through the pipes 52, 53, and 54. The needle valve 109 will close the port 111 when the chamber 35 is full. Simultaneously the needle valve 104 will be unseated and allow compressed air from the cylinder 37 to pass through pipes 50 and 51 and force the fluid from the chamber 35 into the chamber 34 through the pipe 42. The valve 112, needle valve 114, and float 115 in the chamber 34 will function the same as in the chambers 35, 36, there being sufficient compressed air in the chambers 35, 36, and 37 to force the fluid from the chamber 34 into the chamber 33 through the pipe 43, air above the fluid entering the chamber 33 will be vented to atmosphere through pipe lines 118, 119, 120, and 121.

From the foregoing it will be seen that the high pressure air entrapped in the chamber 37 has by successive expansion elevated the fluid from the chamber 37 to chamber 33 the pressure being reduced at each expansion but still remaining sufficiently compressed to effect lifting of the fluid from one lifting chamber to the one above it before the pressure is reduced below a point of further effective expansion. The pressure in the chamber 37 is obviously greatest when first charged with high pressure air from the chamber 17, hence capable of lifting the fluid the greatest distance during the first expansion, viz. when transferring the fluid from chamber 37 to 36; for example, if 250 lbs. of air pressure is employed the chamber 17 may be approximately 500 ft. in length. During the first expansion the pressure will be reduced to approximately 125 lbs. therefore capable of further expansion and of lifting fluid approximately 250 ft. during the second expansion, i. e. from chamber 36 to chamber 35, hence the chamber 16 may be approximately 250 ft. in height. During the second expansion the pressure in the chambers 36 and 37 will be equalized or reduced to approximately 125 lbs. the expansion being capable of lifting the fluid from the chamber 35 to 34 or a distance of 166 ft. The air pressure in the chambers 35, 36, and 37 is then equalized, i. e. at the completion of the third expansion after the fluid has been lifted from the chamber 34 to 33. Air pressure in the chambers 34, 35, 36, and 37 is then equalized and the pressure reduced to approximately 83 lbs., at which time the original pressure of 250 lbs. has been reduced to approximately 83 lbs. and is not employed for further lifting of fluid unless desired. At the moment the fluid has been transferred from chamber 34 to 33 the weight of the float 115 will unseat the valve 114 and allow compressed air in the chamber to enter pipes 53 and 54, also pipe 130 which passes through the chamber 33 and enters a valve cage 131 in a head 132 which forms a division between the chambers 33 and 13.

As previously referred to the pipes 53 and 54 serve as vent pipes during the elevating of the fluid from chamber 37 to 34. However when the valve 114 is opened by the float 115 the expansion of air in the chamber through the pipe 130 will lift a ball check valve 134 and allow air in the pipe 130 to exert pressure on a piston 135 on the stem of a valve 136 normally held seated by an expansion spring 137 and closing a port 138 communicating with the high pressure air chamber 13. The pressure exerted on the piston 135 by the expansion of air from the chamber 34 plus the high pressure air in the chamber 13 through port 138 in the head 132 will unseat the valve 136 which will allow high pressure air to pass through the port 138 and a port 140 and actuate a balanced piston valve 142 in order to form communication between the high pressure chamber 13 and the lifting chamber 33. It will be noted that the outer end of the pipe 54 is reduced at 54^a in order to prevent air from the chamber 34 escaping too rapidly and to insure the lifting of the check valve 134.

The piston valve 142 consists of three pistions 143, 144, and 145, connected by reduced portions 142^a and is slidable in a bore 146 and normally held in the position shown in Fig. 3 by an expansion spring 147. When in this position the piston 144 closes a port 148 thereby preventing high pressure air from the chamber 13 entering the chamber 33, also opening vent port 149 between the pistons 144 and 145. When the valve 137 is actuated, the piston valve 142 will be moved over (against the resistance of the spring) closing the vent port 149 and opening the port 148 which will allow high pressure air from the chamber 13 to enter the chamber 33 through the port 148 and a port 150.

High pressure air entering the chamber 33 will force the fluid therein into the chamber 32 through pipe 44. When the chamber 33 is practically empty the float valve 152 will pull the needle valve 153 from its seat and open a port 154 which will admit air pressure in the chamber 33 to act on the pis-

ton 142 and return same to normal position cutting off any more high pressure air entering same.

The high pressure air entrapped in the chamber 33 will then pass up pipe 118 and force the fluid in chamber 32 into the chamber 31 through pipe 45. Expansion of air in the chambers 32 and 33 which is then reduced in pressure but equalized will pass through pipe 119 and force the fluid in the chamber 31 into the chamber 30 through pipe 45. In a like manner expansion of air in the chambers 31, 32, and 33 will pass through pipe 120 and force the fluid in chamber 30 through pipe 46 to storage.

During the filling of the chambers 30, 31, and 32, needle valves 156, 157, and 158 connected to floats 160, 161, 162, and pivoted levers 164, 165, and 166 connected to valves 167, 168, 169 normally closing the upper ends of the fluid transfer pipes 43, 44, 45, and 46 function in the same manner as in the chambers 33, 34, 35, 36, and 37, the lower end of the transfer pipes being provided with check valves 43^a, 44^a, 45^a, and 46^a. Immediately after the fluid in the chamber 34 has been transferred to the chamber 33 the chamber 37 will again be filled with fluid entering same by gravity and the operation repeated as previously described.

In the event that the supply of compressed air should be cut off during the operation of the fluid lift and fluid partially filling the chambers 36 and 37 after the air in the chamber 37 had been reduced below expansion, the fluid lift would be rendered inoperative, because due to the normal position of the piston valve 66 no high pressure air could enter the chamber 37, nor could this chamber fill and operate float 80 because the vent through pipe 51 would be closed by needle valve 104.

In order to continue operation air pressure in excess of that ordinarily employed is admitted to increase the pressure in the high pressure chambers, this extra pressure will enter a port 170 in the division plate 172 and act on a piston 173 slidable in a bore 173^a formed in said division plate which when moved over against the action of a spring 174 will open a port 175 which will allow the pressure developed in the chamber 16 to force the fluid from the chamber 36 to chamber 35, and when empty the needle valve 104 will be opened by float 105 and operation continued as heretofore described. A branch pipe 51^a forms communication between the bore 173^a and the vent pipe 51, and is provided to permit escape of air during movement of the piston 173, or prevent pressure developing in the space back of the piston. The chamber 37 will eventually be relieved of compressed air through the vent pipes after the chamber 34 has been discharged, thus allowing it to fill by gravity, it being noted that the piston 173 normally closes the port 175 and only operates when excessive high pressure air is employed.

From the foregoing it will be seen that fluid entering the chamber 37 is lifted from that chamber to chamber 33 by successive expansions of compressed air, then lifted again from the chamber 33 through the chambers 32, 31, and 30, by another series of expansions and finally discharged at the top of the well.

Although it would be possible to raise the fluid by a single expansion, an excessive pressure would be required. By employing a plurality of fluid chambers the maximum effectiveness or energy of the initial pressure may be obtained, i. e. by admitting compressed air successively into a plurality of superimposed chambers. The fluid may be raised from the chamber to another in an economical manner. For example, 100 lbs, of air pressure will sustain a 250 foot column of water; by admitting this air into another chamber the fluid therein may be raised another 115 ft.

It will be understood however that by substituting another chamber 33 and head 132 with the valves therein another series of fluid lifting and high pressure chambers may be provided to lift the fluid still further and this system can be employed as often as necessary depending upon the depth of the well.

While we have shown an embodiment of our invention especially adapted for raising or elevating hydrocarbons from oil wells, it will be understood that it may be applied with equal facility to the lifting of fluids, such as water, from deep water wells, or for pumping any kind of slush or other fluid, or semi-fluid materials.

We claim:

1. A fluid lift comprising a plurality of high pressure air chambers, a plurality of fluid lifting chambers interposed between said high pressure air chambers, conduits connecting said fluid lifting chambers, conduits connecting said high pressure air chambers, and means for controlling the admission of compressed air from said high pressure air chambers to said lifting chambers to effect a plurality of expansions of compressed air in said fluid lifting chambers.

2. A fluid lift comprising a plurality of fluid lifting chambers, a plurality of high pressure air chambers between said fluid lifting chambers, valve operated means for admitting compressed air from said high pressure air chambers to the lowermost of said fluid lifting chambers when filled with fluid, valve operated means for cutting off admission of compressed air from said high pressure air chambers to the lowermost of said fluid lifting chambers when the fluid in the lowermost of said fluid lifting chambers has been transferred to the fluid lifting chamber above it, fluid operated valves in the succeeding fluid lifting chambers to admit com-

pressed air from said lowermost fluid lifting chamber to force fluid from one fluid lifting chamber to the one above it by successive expansion of the compressed air in the lowermost of said fluid lifting chambers.

3. A fluid lift comprising a plurality of fluid lifting chambers, a plurality of high pressure chambers interposed between said fluid lifting chambers, pipe lines passing through said fluid lifting chambers and connecting said high pressure chambers, a pipe extending from the lower end of each fluid lifting chamber through the high pressure chamber above through the fluid lifting chamber above the high pressure chamber and terminating adjacent the upper end of the fluid lifting chamber for transferring fluid from one fluid lifting chamber to the one above it, pipe lines in said fluid lifting chambers for first venting the air from said fluid lifting chambers, then admitting air from the high pressure chambers to force the fluid from one lifting chamber to the one above, and valve mechanism operated by the rise and fall of the fluid entering the fluid lift and the fluid lifting chamber for controlling the venting of air in the fluid lifting chambers and the admission of air from the high pressure chambers to force the fluid upward by successive expansions of compressed air from one fluid lifting chamber to the one above it.

4. A fluid lift comprising a plurality of fluid lifting chambers, a plurality of high pressure chambers interposed between said fluid lifting chambers, pipe lines passing through said fluid lifting chambers and connecting said high pressure chambers, a pipe extending from the lower end of each fluid lifting chamber through the high pressure chamber above through the fluid lifting chamber above the high pressure chamber and terminating adjacent the upper end of the fluid lifting chamber for transferring fluid from one fluid lifting chamber to the one above it, pipe lines in said fluid lifting chambers for first venting the air from said fluid lifting chambers, then admitting air from the high pressure chambers to force the fluid from one lifting chamber to the one above, a check valve in the lowermost of said fluid lifting chambers for admitting fluid therein, a valve between the lowermost of said fluid lifting chambers and the high pressure air chambers adapted to open and close ports at proper intervals to exhaust the air from the lowermost of said fluid lifting chamber and admit air from said high pressure air chambers for successive expansions to force the fluid in the succeeding lifting chamber upward, and valve mechanism operated by the rise and fall of fluid in the lowermost of said fluid lifting chamber to actuate said avlve.

5. A fluid lift comprising a plurality of fluid lifting chambers, a plurality of high pressure air chambers interposed between said fluid lifting chambers, a check valve in the lowermost of said fluid lifting chambers for admitting fluid therein, a head between the lowermost of said fluid lifting chambers and the high pressure air chamber above it, a balanced piston valve slidable in a bore in said head adapted to open vent ports in said head for exhausting the air in the lowermost of said fluid lifting chambers while being filled with fluid, then closing said vent ports when the lowermost of said fluid lifting chambers are filled with fluid and opening ports from said high pressure air chambers and again opening said vent ports and closing said ports from the high pressure air chamber when the fluid in the lowermost of said fluid lifting chamber has been transferred to the fluid lifting chamber above it, needle valves for admitting compressed air alternately to each end of the bore in said head to actuate said balanced piston valve, and floats for actuating each of said needle valves.

6. A fluid lift comprising a plurality of fluid lifting chambers, a plurality of high pressure air chambers interposed between said fluid lifting chambers, each of said high pressure air chambers being of greater length than the one above it, conduits connecting said fluid lifting chambers, conduits connecting said high pressure air chambers, and means for controlling the admission of compressed air from said high pressure air chambers to said lifting chambers to effect a plurality of expansions of compressed air in said fluid lifting chambers.

In testimony whereof we affix our signatures.

CHARLES H. HARDIE.
WILLIAM JONES.