

May 17, 1927.

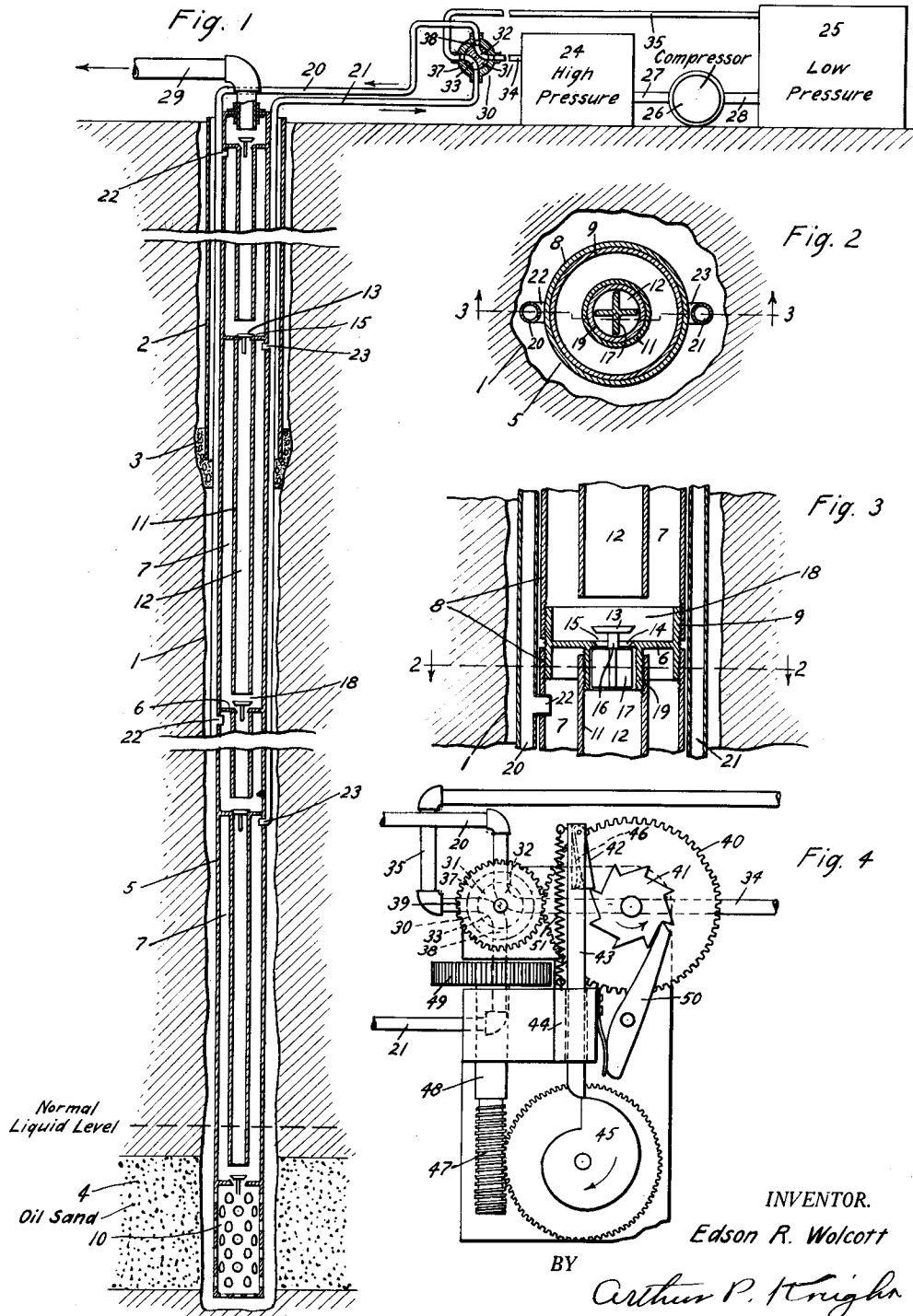
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APPARATUS FOR PUMPING LIQUIDS

Filed Oct. 16, 1924

2 Sheets-Sheet 1



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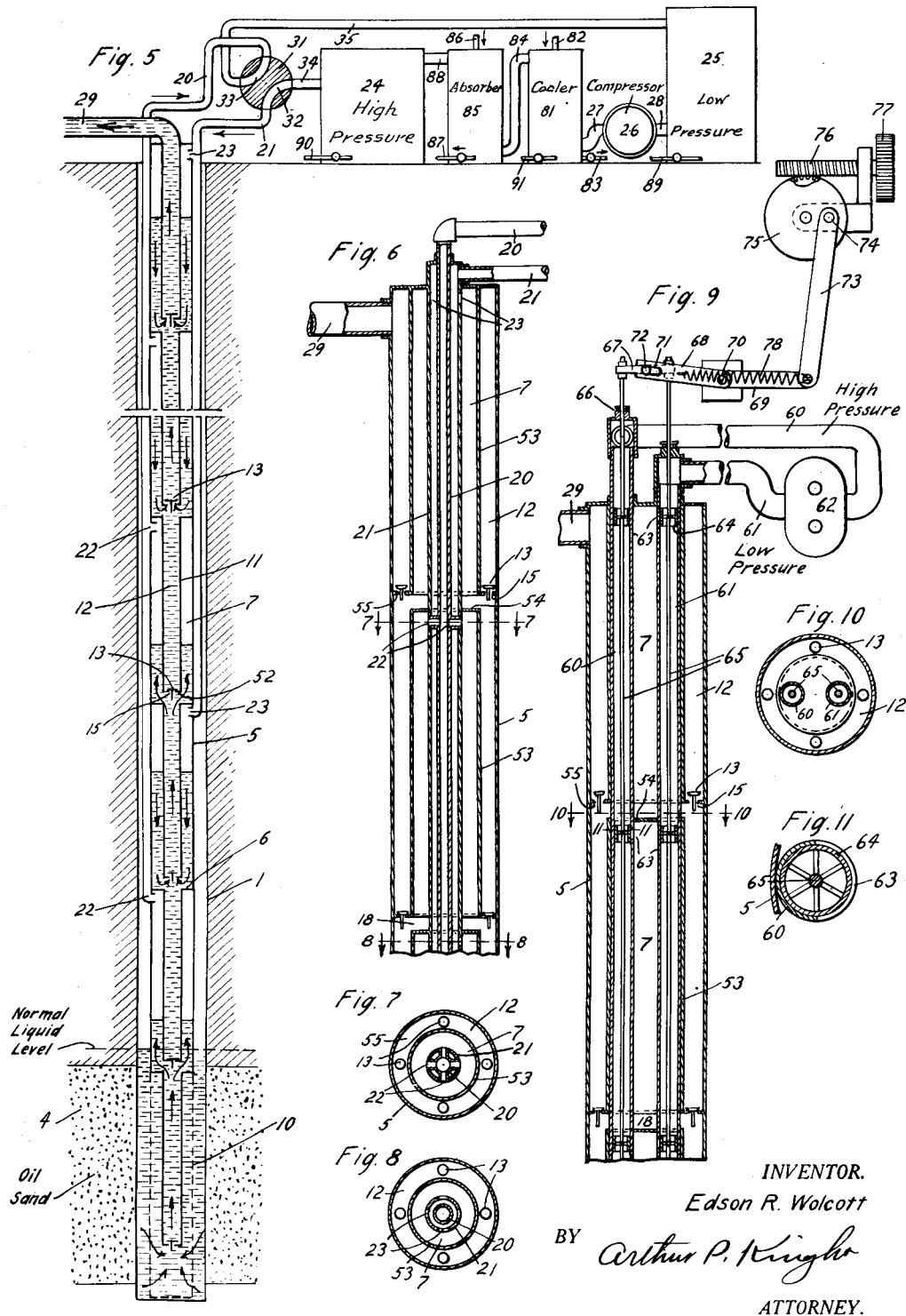
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE.

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APPARATUS FOR PUMPING LIQUIDS.

Application filed October 16, 1924. Serial No. 743,972.

My invention relates to pumps adapted to be operated by means of air or other gas under pressure, and particularly to pumps of the above type for use in pumping liquids through considerable vertical heights, as in pumping liquids from wells, and to a method of operating such pumps. My invention is particularly adapted for use in pumping oil from oil wells but may also be advantageously used for pumping other liquids.

An important object of the invention is to provide a pump for the above purpose which is simple in operation and which is substantially free from moving parts which are subjected to excessive wear during operation and between which tight joints must be maintained. A further object of the invention is to provide a pump which is effective, durable, and economical in operation. A further object is to provide a pump adapted for use in pumping liquids from wells, in which substantially all the moving parts are located above the surface of the ground so as to facilitate inspection and repair thereof. A further object of the invention is to provide in certain cases for recovery from the air or gas used as an operating medium, of volatile constituents entrained by such air or gas from the liquid being pumped, for example, the recovery of gasoline in pumping hydrocarbon oil.

My improved liquid pump comprises essentially a plurality of working chambers located one above another, means for creating relatively high and low pressures in alternate chambers and for periodically reversing the condition in all the chambers simultaneously, from high pressure to low pressure, and vice versa, and suitable passage means and valve means between said chambers, the arrangement being such that liquid is forced from each chamber in which high pressure exists into the low pressure chamber next above the same, so that the above-described alternate applications of high and low pressure to the respective chambers causes the liquid being pumped to be continually moved upward throughout the height of the pump. An effective means of applying the above-described difference in pressure in adjoining chambers consists in creating a condition of pressure and vacuum in alternate chambers, and periodically changing the condition in each chamber from pressure to vacuum, and vice versa.

The accompanying drawings illustrate em-

bodiments of my invention and referring thereto:

Fig. 1 is a partially diagrammatic vertical section of an oil well provided with a pump according to my invention.

Fig. 2 is a horizontal section through such an oil well and pump, on line 2—2 in Fig. 3.

Fig. 3 is an enlarged vertical section on line 3—3 in Fig. 2.

Fig. 4 is a side elevation of a means for controlling the application of pressure and vacuum to the respective chambers.

Fig. 5 is a diagrammatic vertical section of a modified form of the invention.

Fig. 6 is a partial vertical section of another modification of the invention.

Figs. 7 and 8 are horizontal sections on lines 7—7 and 8—8 respectively in Fig. 6.

Fig. 9 is a partial vertical section of another modified form of the invention.

Fig. 10 is a horizontal section on line 10—10 in Fig. 9.

Fig. 11 is an enlarged horizontal section of a control valve for the form of the invention shown in Fig. 9, taken on line 11—11 in said figure.

In the form of my invention shown in Figs. 1 to 3 my pump is shown as applied particularly in connection with an oil well, the bore of which is indicated at 1. Such well may be provided with the usual water string or casing 2 which may be cemented off as at 3 to prevent entrance of water into the portion of the bore in which the oil enters, for example from an oil sand indicated at 4. The pump comprises a main vertical casing indicated at 5 and extending substantially throughout the depth of the bore hole and provided at intervals with horizontal partitions 6 which divide the space within said casing 5 into a plurality of vertical chambers 7 located contiguously one above another so as to form a continuous series of such chambers. Casing 5 must extend to such a depth in the well that the lowermost chamber 7 extends below the normal oil level of such well. Each of the chambers 7 is of such height that the oil being pumped may be raised from one chamber to the next by means of the pressure and vacuum available. For example each of said chambers may be from 20 to 100 feet or more in height. In practice it is convenient to form casing 5 of a plurality of sections or units as indicated at 8 in Fig. 3, there being for example one of such casing units corresponding to

each vertical sections 7, and the adjoining units 8 being connected together for example by a bushing or coupling member 9 in each of which is formed or mounted one of the horizontal partitions 6. Casing 5 is provided at its lower end, and below the lowermost partition 6, with a perforated portion 10 which is adapted to permit the entry or flow of oil into the interior of said casing. Suitable discharge means such as pipe 29 are provided for conducting the oil from the pump to a pipe-line, storage tank, or other destination.

The chambers 7 above described constitute the air or gas chambers to which pressure and vacuum are alternately applied, and within each of said chambers there is provided an inner vertically extending cylindrical tube or pipe 11, the interior of which constitutes a vertical passage or oil chamber 12. Said cylindrical tubes 11 extend downwardly from each partition 6 to within a short distance of the bottom of the corresponding chamber 7, so as to provide a communication between the air or gas chambers and the oil passages, as at 18. There is also provided between each of said oil chambers or passages 11 and the chamber 7 immediately above the same, a single valve port 15 having suitable valve means such as check valve 13 adapted to be opened by an excess in pressure from below so as to permit the flow of oil upwardly therethrough and to be closed by an excess of pressure from above so as to prevent the downward return of any oil from above. As shown in Fig. 3 the respective cylindrical tubes 11 may be screwed or otherwise mounted at their upper ends upon suitable supporting means 19 on the corresponding partitions 6. Each check valve 13 may be adapted to cooperate with a valve seat 14 so as to control communication through opening 15 in partition 6 and suitable means may be provided for maintaining check valve 13 in proper position. For this purpose the stem 16 of said valve may be provided with ribs or vanes 17 adapted to engage guide means, for example, the inner wall of the supporting means 19 so as to guide the valve vertically, and adapted upon opening movement of the valve to engage the under side of partition 6 so as to limit such opening movement and retain the valve in such position as to be closed upon application of pressure from above.

Suitable means are provided for alternately applying high pressure and low pressure to the respective chambers 7 in such manner that opposite conditions prevail at all times in alternate chambers. Such means may comprise pipes 20 and 21 adapted to conduct air or other gas to and from said chambers, pipe 20 being connected to every alternate chamber 7 as at 22 and pipe 21

being connected to the remaining chambers 7 as at 23. High pressure tank or receiving means 24 and low pressure tank or receiving means 25 are also provided, together with suitable means for maintaining conditions of high and low pressure respectively in said tank, for example, an air compressor indicated diagrammatically at 26 may be connected by pipes 27 and 28 to the respective tanks in such manner as to continually exhaust the air or gas from low pressure tank 25 and to discharge the same into the high pressure tank 24. The pressure maintained in the high pressure tank 24 may be any suitable pressure, preferably greater than atmospheric, while any relatively low pressure may be maintained in tank 25. It is of advantage however, in order to obtain the maximum lift in each section of the pump, to maintain a vacuum in said tank 25, or in other words a pressure below atmospheric. In the description which follows it will therefore be assumed that a pressure greater than atmospheric will be maintained in tank 24, and a vacuum in tank 25. Instead of the above arrangement, if air is used as the working medium, a vacuum pump may be connected to tank 25, with an open discharge, and a compressor having an open intake may be connected to tank 24, or any other suitable means may be provided for maintaining the desired vacuum and pressure in the respective tanks. Means are also provided for alternately establishing communication between pipes 20 and 21 and tanks 24 and 25. For this purpose an intermittently operated double control four-way valve may be provided as indicated at 30, said valve being provided with a rotatably mounted member 31 provided with ports 32 and 33 adapted to control communication, upon rotation of said rotary member 31, between pipes 20 and 21 and pipes 34 and 35 leading respectively to the pressure tank 24 and the vacuum tank 25. The rotary member 31 may be operated by any suitable mechanical means in such manner as to be periodicaly rotated through one quarter of a revolution so as to reverse the connections between said pipes.

In Fig. 4 there is shown a mechanism adapted to operate the double control valve in this manner. Rotary member 31 may be mounted to rotate in a cylindrical bearing 37, the respective pipes 20 and 21, 34 and 35 being connected to passages 38 in said bearing adapted to register with the ports 32 and 33 in the rotary member. Said rotary member is adapted to be operated through gear wheels 39 and 40 upon operation of ratchet wheel 41, for example by means of pawl 42. Said pawl may be pivoted at the upper end of a rod 43 adapted to slide vertically in bearing 44. Cam wheel 45 is adapted upon rotation in the direction indi-

cated by the arrow to gradually raise and then suddenly drop bar 43 together with pawl 42. In the upward movement, said pawl passes over the teeth of the ratchet wheel 41 without operating the same, but upon the sudden dropping of bar 43, pawl 42 engages a tooth of said wheel and causes sufficient rotation of the same to move rotary member 31 through one quarter revolution. Bar 43 may be made heavy enough to cause it to operate by gravity, or spring means 51 may be provided for this purpose. Suitable means such as leaf spring 46 may be provided for permitting the pawl to be pressed inwardly during the upward movement of rod 43 so that the pawl may pass over the ratchet wheel and for causing the pawl to be forced outwardly into engagement with said wheel so as to effect rotation on the downward movement of bar 43. Catch means indicated at 50 may also be provided to prevent rotation of ratchet wheel 41 in the reverse direction during upward movement of bar 43. Cam member 45 may be operated for example by means of a worm gear 47 so as to produce a slow motion of said cam member, the shaft 48 of said worm gear being provided with suitable driving means such as gear wheel 49 which may be connected to any source of motive power for example to an electric motor not shown.

It will be understood that for the purpose of clearness the parts are somewhat distorted in the drawings, for example, each chamber 7 is represented as of greater diameter in proportion to its height than is actually the case. Furthermore only portions of the entire height of the pump are shown, each of the brakes in Fig. 1 representing the omission of at least several hundred feet of the well.

The operation of the above described form of my invention is as follows:

With the parts in the position shown, the lowermost chamber 7 and every second chamber thereabove throughout the height of the pump is in communication with the vacuum tank 25 and a condition vacuum therefore exists in said chambers. The remaining chambers 7 on the other hand are in communication with pressure tank 24 so as to maintain a pressure greater than atmospheric within the latter chambers. At this time oil is being drawn up into the lowermost chamber 7 through the valve opening 15 at the bottom thereof due to the vacuum in said chamber. In the second chamber from the bottom a condition of pressure exists and in the third chamber one of vacuum and the combined effect of such pressure and vacuum is to force oil from said second chamber through the oil passage 12 within said chamber and into said third chamber. This action is repeated in every pair of chambers throughout the height of the pump

and since a condition of pressure exists in the uppermost chamber 7 oil is also being discharged through pipe 29 to the storage means. As long as the rotary member 31 of valve 30 remains in the position shown the above conditions will be maintained and the period allowed for such operation to continue should be such as is found by practice sufficient to permit the maximum displacement of oil from each section to the one above or in other words until the lifting of the oil has practically ceased under these conditions. The operating mechanism for rotary member 31 is so timed that at the expiration of such period, said rotary member will be moved one quarter revolution so as to reverse the conditions in the respective chambers, pressure being then applied to the lowermost chamber, vacuum to the next, etc., alternately to the top of the pump. The operations occurring in each section of the pump are therefore an intermittent raising of oil within the pressure chamber 7 during which the valve 13 directly below said chamber is open while the one above is closed, followed by a discharge of such oil through the corresponding passage 12 and into the chamber 7 next above, at which time the valve 13 below the former chamber is closed and the valve leading into the chamber next above is open. The gaseous medium used for creating pressure and vacuum in the chambers may be air, or in case of pumping hydrocarbon oil from oil wells such medium may advantageously consist of hydrocarbon gas, in order to eliminate evaporation of volatile hydrocarbons from the oil and also to prevent possibility of explosion which might result if air were used.

In the form of the invention shown in Fig. 5 the construction is similar to that above described except for the location of valves 13. In this case the opening between each oil passage 12 and the working chamber 7 directly above the same is open at all times, while the lower end of each of the inner cylindrical tubes 11 is closed as at 52 and is provided with a valve port 15 adapted to be controlled by check valve 13. The sequence of operations is the same as in the form of the invention first described but this modification possesses the advantage that any oil which is once forced up into one of the oil passages 12 can not return to the corresponding working chamber 7 upon the reapplication of vacuum thereto. All of such passages are therefore continually filled with oil as indicated in Fig. 5, and there is no unnecessary movement of the oil. In either case, however, there is only a single check valve between each working chamber and the next. The path of the oil, when the parts are in the position shown is indicated by the arrows in said figure.

I have also shown in Fig. 5 a simple means

which may be used in connection with any of the modifications of my invention, for recovering from the air or gas used as a working medium in the pump any volatile constituents which may be removed by such air or gas from the liquid being pumped. For this purpose the discharge pipe 27 leading from the compressing means 26 may lead to suitable cooling or condensing means, such as cooler 81 provided with inlet and outlet pipes 82 and 83 for cooling medium, for example water. From cooler 81 pipe 84 may lead to an absorber 85 through which the compressed and cooled air or gas passes upwardly, while a suitable absorbing medium is passed through preferably in the reverse direction, inlet and outlet pipes 86 and 87 being provided for supplying and carrying away such absorbing medium. From the absorber, pipe 88 leads to the high pressure receiving means 24. The absorbing medium passing from the absorber may be treated in any suitable manner to recover the volatile material absorbed thereby, for example, it may be subjected to a partial distillation. The liquid used as an absorbing medium will depend of course upon the volatile constituent which is to be recovered. In pumping hydrocarbon or mineral oil from oil wells, the volatile constituents which may be carried off by the air or gas used as working medium will consist of the more volatile hydrocarbons, and any solvent for such materials which is itself not readily volatile may be used, such as naphtha or mineral seal oil. Upon subsequent distillation of the absorbing oil drawn off through pipe 87, a good quality of gasoline may be recovered, and the absorbing oil may then be cooled and returned to pipe 86 leading to the absorber. Provision may also be made for drawing off from the low and high pressure receiving means, and from the cooler, any volatile constituents which may condense and collect at these points, suitable drain pipes 89, 90, and 91 being provided for this purpose if desired.

As shown in Fig. 6, I may form all of the vertically extending tubes or pipes concentrically one within another, for example, each of the oil passages in such case may be located between the outer casing 5 and an inner casing section 53, the interior of each of said inner casing sections constituting a working chamber 7. Pipes 20 and 21 may be arranged one within the other and may be disposed centrally within said working chambers 7 and provided with passages 22 and 23 leading from the respective pipes 20 and 21 into the alternate working chambers throughout the height of the pump. Each chamber 7 may be closed at the top by means of a head member 54 attached to or formed on the corresponding casing

section 53, and each of the oil passages 12 may be closed at the bottom by means of an annular horizontal partition 55 extending between the outer and inner casings 5 and 53. The annular opening 18 above the head member 54 of each chamber 7 is adapted to permit communication between the corresponding oil passage and the chamber 7 next above. Partitions 55 are provided with suitable valve ports 15 and check valves 13 adapted to be operated as above described to control communication between the respective oil passages. The operation of this form of the invention is substantially the same as that shown in Fig. 5 and does not require detailed description. Assuming that a condition of pressure exists in the upper chamber 7 and one of vacuum in the lower chamber 7 the valves 13 will be in the position shown and oil will therefore be drawn up into the lower chamber 7 and discharged from the upper chamber through the corresponding oil passages 12 and discharge pipe 29.

Instead of connecting the two gas or air conducting pipes 20 and 21 to alternate working chambers 7, and providing control valve means located at the surface for alternately applying pressure and vacuum to said pipes, I may in some cases provide a connection from each of said pipes into each working chamber and control the communication between said pipes and said working chambers through valve means located within the pipes themselves as shown in Fig. 9. In this form of the invention one of the gas or air supply pipes for example pipe 60 may be permanently connected to a source of pressure and the other pipe 61 to a source of vacuum. For this purpose said pipes may be connected respectively to suitable pressure tank and vacuum tank, said tanks being provided with suitable means for maintaining pressure and vacuum therein. Or I may connect pipe 60 to the discharge, and pipe 61 to the intake, of an air compressor or blower, indicated diagrammatically at 62. Pipes 60 and 61 may be provided with valve ports 63 and with suitable valve means such as sliding valves 64 adapted to control communication through said valve ports. Said valves 64 may be mounted on operating means such as valve rods 65 extending throughout the height of pipes 60 and 61 and extending through stuffing boxes 66 at the upper ends of said pipes so as to maintain tight working joints at these points. Valve ports 63 are arranged alternately in successive working chambers 7 so that when the valve port 63 connecting one of the gas or air supply pipes to a certain working chamber 7 is open the valve port connecting the other of said pipes to the said chamber is closed, while in the next adjoining

working chamber 7 the location of the valve ports and valves therefor is such that the conditions are just the reverse of those in the first mentioned working chamber. In this form of the invention casing 5 is provided as in the other forms above described with suitable oil passages 12, and with valve ports 15 and check valves 13 adapted to control communication between said passages.

10 Discharge pipe 29 may be connected to the uppermost oil passage or chamber 12 so as to permit discharge of oil therefrom. Suitable operating means are provided for valve rods 65 to effect periodic movement thereof

15 so as to reverse the connections from pipes 60 and 61 to each of the working chambers 7. Said valve rods may be provided for example with a cross-head 67 at their upper ends and any suitable means may be

20 provided for alternately moving said cross-head up and down. For this purpose a quick-acting lever arrangement comprising levers 68 and 69 pivoted at 70 may be connected at one end to said cross-head, for

25 example by means of slot 71 in lever arm 68 engaging a pin 72 on said cross-head, and connected at the other end to a link 73 whose other end is mounted eccentrically, as at 74, on wheels 75. Said wheel 75 may

30 be operated for example by means of worm gear 76 provided with suitable driving means such as gear wheel 77 which may be connected to any suitable source of power, so as to impart an alternate up and down

35 motion to link 73. Suitable means such as a spring 78 may be connected to lever arms 68 and 69 so that when arm 69 is swung by link 73 beyond the dead center position, said spring 78 will cause lever arm 68 to

40 be suddenly swung upward or downward as the case may be so as to raise or lower the valve rods 65 and valves 64.

In the operation of this form of the invention a condition of pressure exists at

45 all times within pipe 60 and a condition of vacuum exists at all times within pipe 61 and the above described operation of the valve means 64 will therefore cause vacuum and pressure to be alternately applied to

50 the respective working chambers 7 so as to effect upward movement of the oil within the oil passages 12 substantially as above described.

In the forms of the invention shown in

55 Figs. 6 to 11 inclusive it will be seen that the gas passage means 20 and 21 or 60 and 61, for applying relatively high and relatively low pressure to the alternate working chambers, extend within such working chambers.

60 Such a construction leads to the maximum utilization, for pumping purposes, of the space which is available within the well casing or water string 2, as it is evident that a working chamber of larger cross-sectional

area may be thus provided within an outer casing of a given size than when the gas passage pipes 20 and 21 are located outside the working chambers as shown in Fig. 2.

In any of the forms of my invention above described, the operating mechanism for the reversing means may be so regulated in speed that the desired time occurs between successive changes from pressure to vacuum, or vice versa, in the respective working chambers. This time should be such as to permit the oil to rise in each vacuum chamber to substantially the maximum possible height. No definite time can be specified. It includes both the time necessary for exhausting the air or gas from one series of alternate chambers, and building up the desired pressure in the remaining chambers, and the time required to raise the column of oil through the necessary height. The time interval will therefore depend upon the depth of the well, the height of each working chamber, the capacity of the pressure vacuum apparatus, the viscosity and density of the oil, and other factors, and must be determined by trial in each case.

It is also realized that in general there will be an appreciable tendency to lag in reaching equilibrium in the lower working chambers, and that this tendency will be especially pronounced in very deep wells. This may be overcome, however, by increasing the size or number of the openings from the air or gas supply pipes into the lower working chambers, so as to provide between the chambers and said supply pipes, a restriction in the air or gas flow varying inversely in proportion to the depth. The exhausting and supplying of air or gas to the working chambers will therefore be substantially uniform throughout the height of the pump.

The discharge of oil from the top chamber of the pumps shown in the drawings is intermittent, as oil will be discharged only when a condition of pressure exists in the uppermost working chamber 7. If it is considered necessary or desirable, in any case, to provide continuous discharge, any of the forms of the invention shown may readily be converted into a duplex pump. For example, a pair of similar but oppositely arranged pumps may be inserted side by side in the well; or vertical partitions may be provided so as to separate the working chamber and the oil passage means in each section vertically into two similar halves, and suitable openings may be provided for admitting air or gas from the respective supply pipes to the two working chambers thus provided at each level. The parts would in such case be so arranged that when pressure is applied to one of the working chambers at a certain level, vacuum is applied to the other one, so

that oil will be continually discharged from one or the other of the working chambers at the top of the pump.

While I have described my improved pump as applied particularly to the pumping of oil from wells, it will of course be understood that it may be used advantageously in pumping any liquid through great heights, and that any gaseous medium may be used for creating the desired condition of pressure and vacuum.

Furthermore, it will be understood that while I have described a pump in which pressure and vacuum are used, my invention comprises broadly the establishment of a difference in pressure between the adjacent chambers. It is only necessary to establish relatively high pressure and relatively low pressure in alternate chambers, and to periodically reverse the condition in each chamber. Such relatively high and low pressures may consist of pressure on the one hand and vacuum on the other, or both such pressures may be greater than atmospheric, if desired, one being sufficiently greater than the other to give the desired pumping action. In some cases, atmospheric pressure may be advantageously used for either the high or low pressure, preferably the latter. Each of the working chambers may then be placed in direct communication with the atmosphere during its low pressure period, and in communication with a source of pressure greater than atmospheric during its high pressure period. The communication to the atmosphere may be secured through a pipe extending throughout the height of the pump, and open to the atmosphere at the surface; for example, in the form of the invention shown in Figs. 9 to 11, pipe 61 may be open to the air above the surface of the ground and pipe 60 may be connected to the discharge side of the air compressor or blower 62. Or if desired, means may be provided for placing each of the working chambers, during its low pressure period, in communication with the air in the well surrounding the casing, so as to provide for more immediate and direct escape of the air or gas from such chambers at the beginning of the low pressure period. For example, in Fig. 9, pipe 61 may be provided with outlet pipes extending through the walls of casing 5 into the air around said casing at intervals throughout the height of the pump, there being, say, one or more such outlets in the portion of said pipe adjacent each chamber 7. Pipe 60 would in such case be connected to the high pressure side of the air compressor or blower as before, while the intake of said compressor would be open to the air.

In any of the above forms of my apparatus for pumping liquids, any number of working chambers may be used, located one above another. The number of chambers required

in any case will depend upon the height through which the liquid must be pumped and the maximum efficient height of each chamber under existing conditions. In pumping from shallow wells, two sections may in some cases be sufficient, but this number may be increased almost indefinitely for pumping from deep wells.

When the relatively low pressure used consists of a vacuum, it is only necessary, in order to provide for complete filling and emptying of each working chamber at each operation of the pump, that the casing extend to such a depth below the normal liquid level in the well, as indicated in Figs. 1 and 5, that upon creation of a vacuum in the lowermost chamber the liquid will be drawn up substantially to the top of said chamber. For this purpose it is desirable, when pumping oil for example, that the top of the lowermost working chamber be not over about 30 feet above the normal liquid level. On the other hand, if the relatively low pressure is itself equal to or greater than the air or gas pressure normally existing in the well, then the casing must extend to such a depth that the liquid will be forced up into the lowermost chamber against the pressure in said chamber during its relatively low pressure period.

What I claim is:

1. A liquid pump comprising a plurality of working chambers located contiguously one above another so as to form a substantially continuous series of such chambers, a liquid conducting passage extending within and substantially coterminous with each of said working chambers, each of said liquid conducting passages communicating at its lower and upper ends respectively with the next higher working chamber, check valve means in each of said liquid conducting passages permitting only upward flow of liquid therethrough, means for creating relatively high pressure and relatively low pressure in alternate working chambers, and means for periodically changing the condition in each working chamber from relatively high pressure to relatively low pressure, and vice-versa.

2. A construction as set forth in claim 1, in which the means for creating relatively high pressure and relatively low pressure in the working chambers include two gas passage means extending within said working chambers and communicating respectively with alternate working chambers.

3. A liquid pump comprising casing means provided with a plurality of working chambers located one above another, a plurality of liquid passage means connecting adjoining working chambers and communicating with said adjoining chambers at the lower portions of said chambers, a single check valve in each of said passage means adapted

to permit flow of liquid through said passage means in an upward direction only, means for creating relatively high pressure and relatively low pressure in alternate
 5 working chambers, and means for periodically changing the condition in each working chamber from relatively high pressure to relatively low pressure, and vice versa.

4. A liquid pump comprising a plurality
 10 of working chambers located contiguously one above another so as to form a substantially continuous series of such chambers, a liquid conducting passage extending within and substantially coterminous with each
 15 of said working chambers, each of said liquid conducting passages communicating at its lower and upper ends respectively with the working chamber within which it extends and with the next higher working chamber,
 20 check valve means in each of said liquid conducting passages permitting only upward flow of liquid therethrough, means for creating pressure and vacuum in alternate working chambers and means for periodical-
 25 ly changing the condition in each of said chambers from pressure to vacuum and vice-versa.

5. A construction as set forth in claim 4, the means for creating pressure and vacuum
 30 in the alternate working chambers including two gas passage means extending within said working chambers and communicating respectively with the alternate working chambers adjacent the upper ends thereof.

35 6. A liquid pump comprising a plurality of working chambers located contiguously one above another so as to form a substantially continuous series of such chambers, a liquid conducting passage extending within
 40 and substantially coterminous with each of said working chambers, each of said liquid conducting passages communicating at its lower and upper ends respectively with the working chamber within which it extends
 45 and with the next higher working chamber, a single check valve in each of said liquid

conducting passages, said check valve being located at the lower end of the respective liquid conducting passage and being adapted
 50 to permit only upward flow of liquid there-through, means for creating relatively high pressure and relatively low pressure in alternate working chambers, and means for periodically changing the condition in each
 55 working chamber from relatively high pressure to relatively low pressure and vice-versa.

7. A liquid pump comprising a casing provided with a plurality of working chambers located one above another, a plurality of
 60 liquid passage means connecting adjoining working chambers and communicating with said adjoining working chambers at the lower portions of said chambers, a single check valve in each of said passage means adapted to open upwardly only, means for
 creating pressure and vacuum in alternate working chambers, and means for periodically changing the condition in each of said
 70 chambers from pressure to vacuum and from vacuum to pressure, said change being effected simultaneously in all of said chambers.

8. A liquid pump comprising a plurality
 75 of working chambers located one above another, liquid conducting passages connecting adjacent working chambers, check valves located in the respective liquid conducting passages and permitting only upward flow of
 80 liquid therethrough, two gas passage means extending substantially throughout the height of said pump and within said working chambers and communicating respectively with alternate working chambers, and
 85 means for alternately applying relatively high and relatively low pressure to said gas passages.

In testimony whereof I have hereunto subscribed my name this 9th day of October, 1924.

EDSON R. WOLCOTT.