

Dec. 4, 1945.

J. F. ROSS

2,390,124

SYSTEM OF PUMPING WELLS

Filed June 27, 1938

9 Sheets-Sheet 1

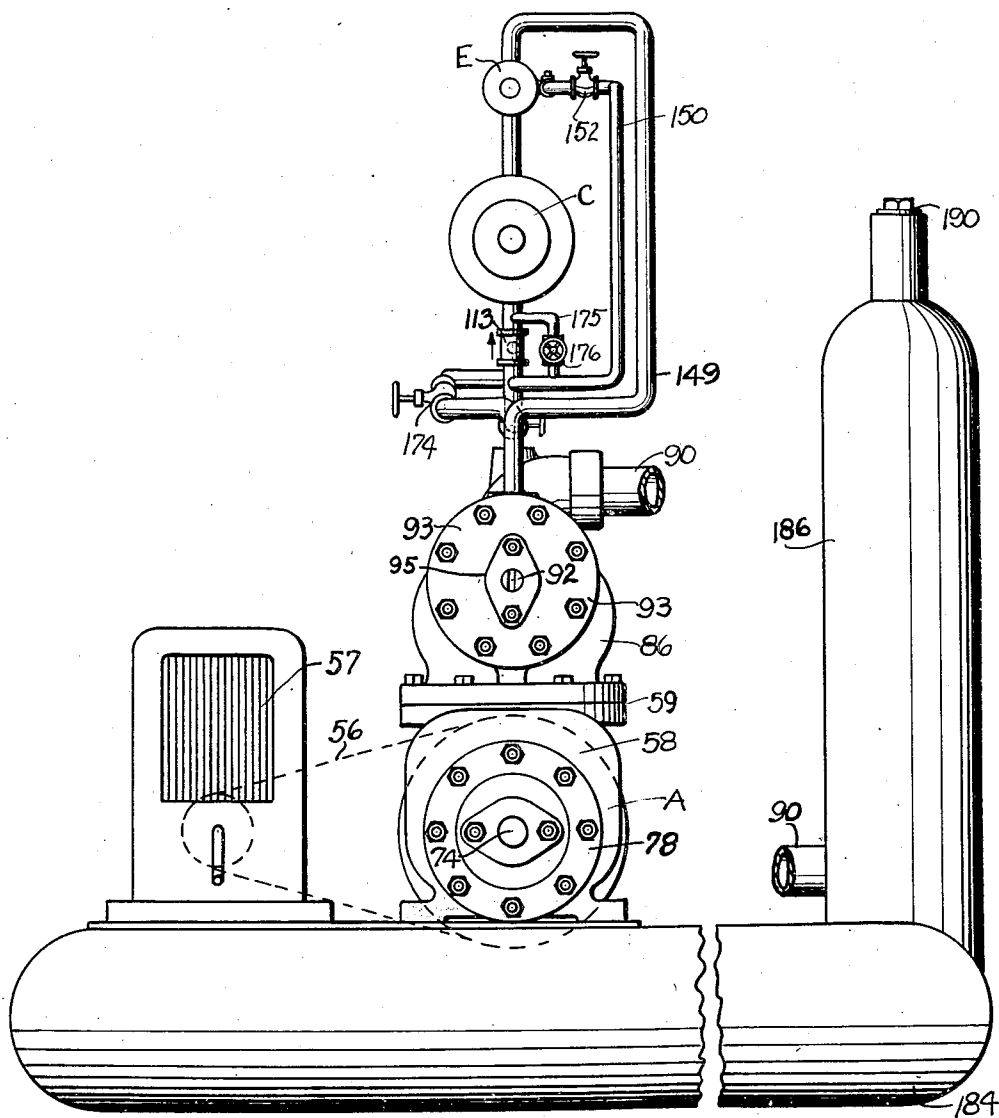


Fig. 1.

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9 Sheets-Sheet 2

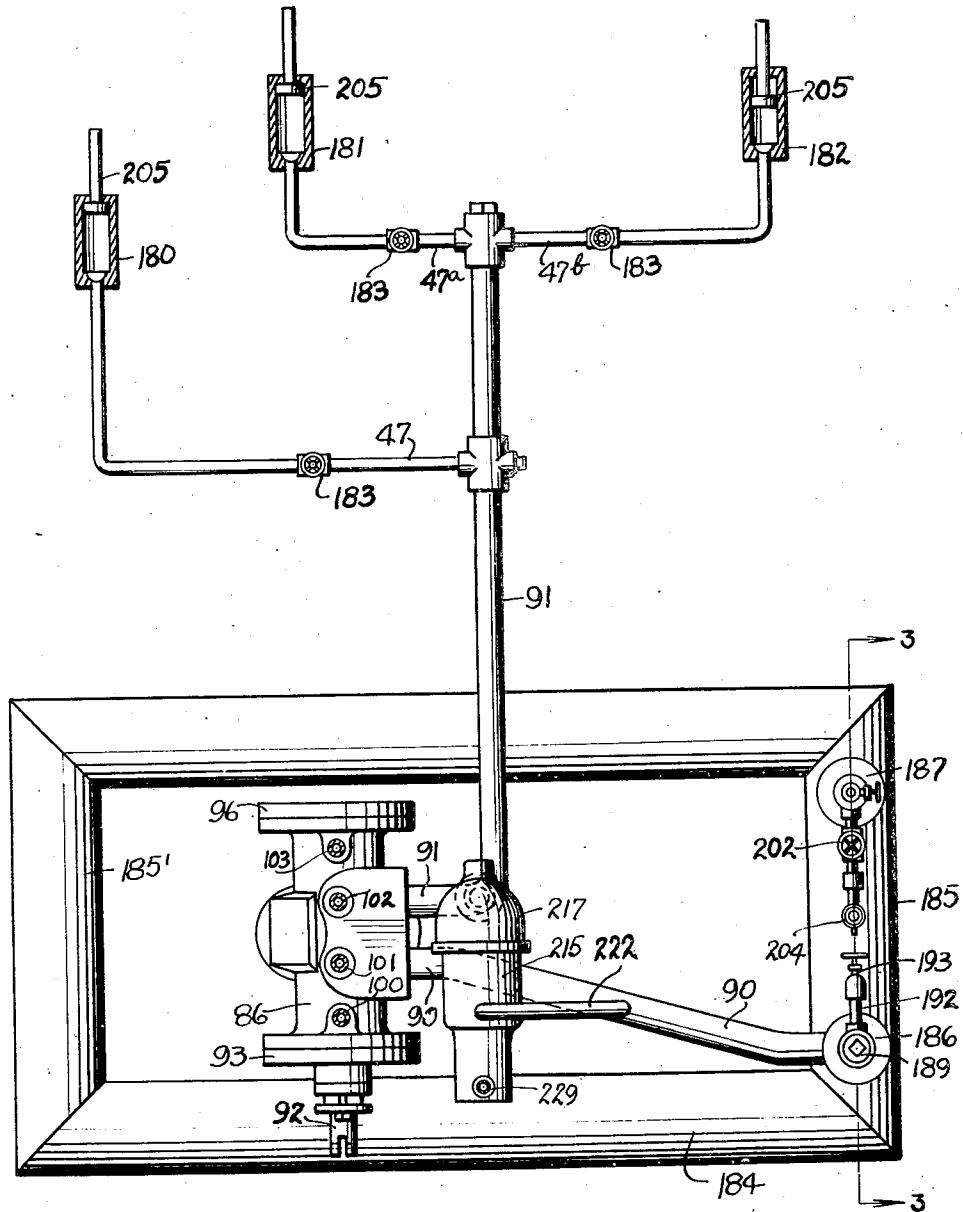


Fig. 2.

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9 Sheets-Sheet 3

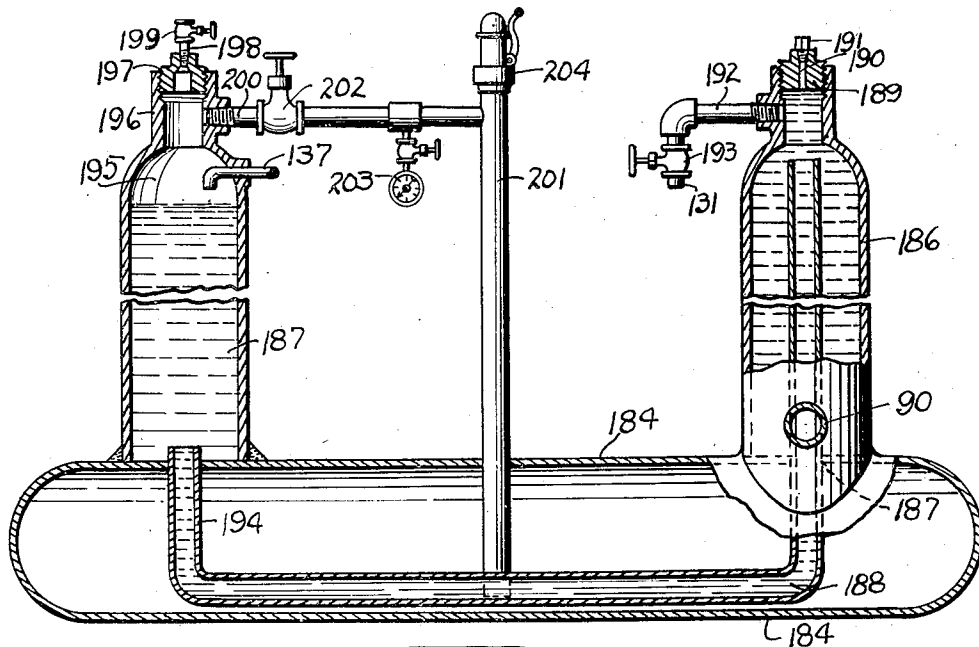


Fig. 3.

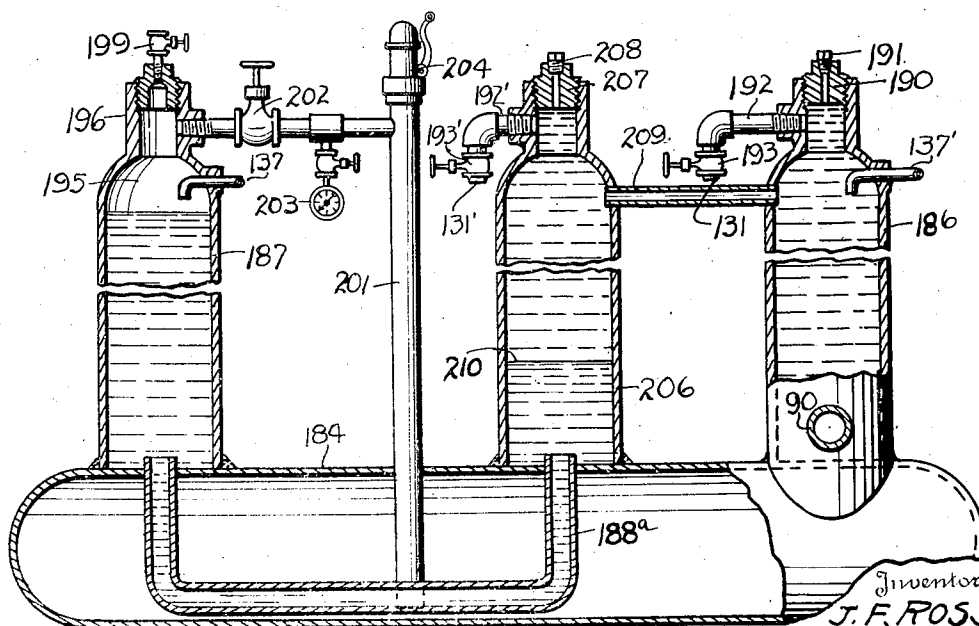


Fig. 4.

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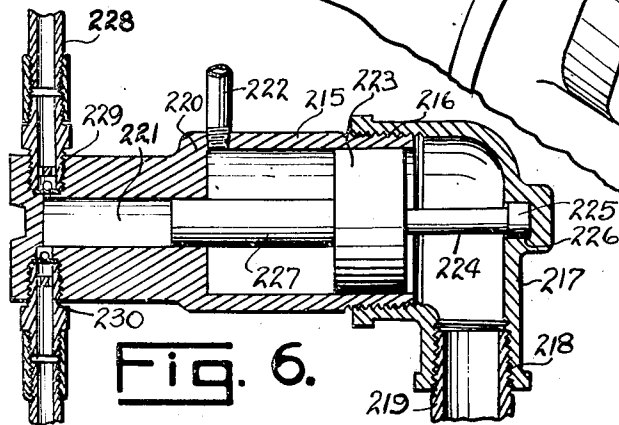
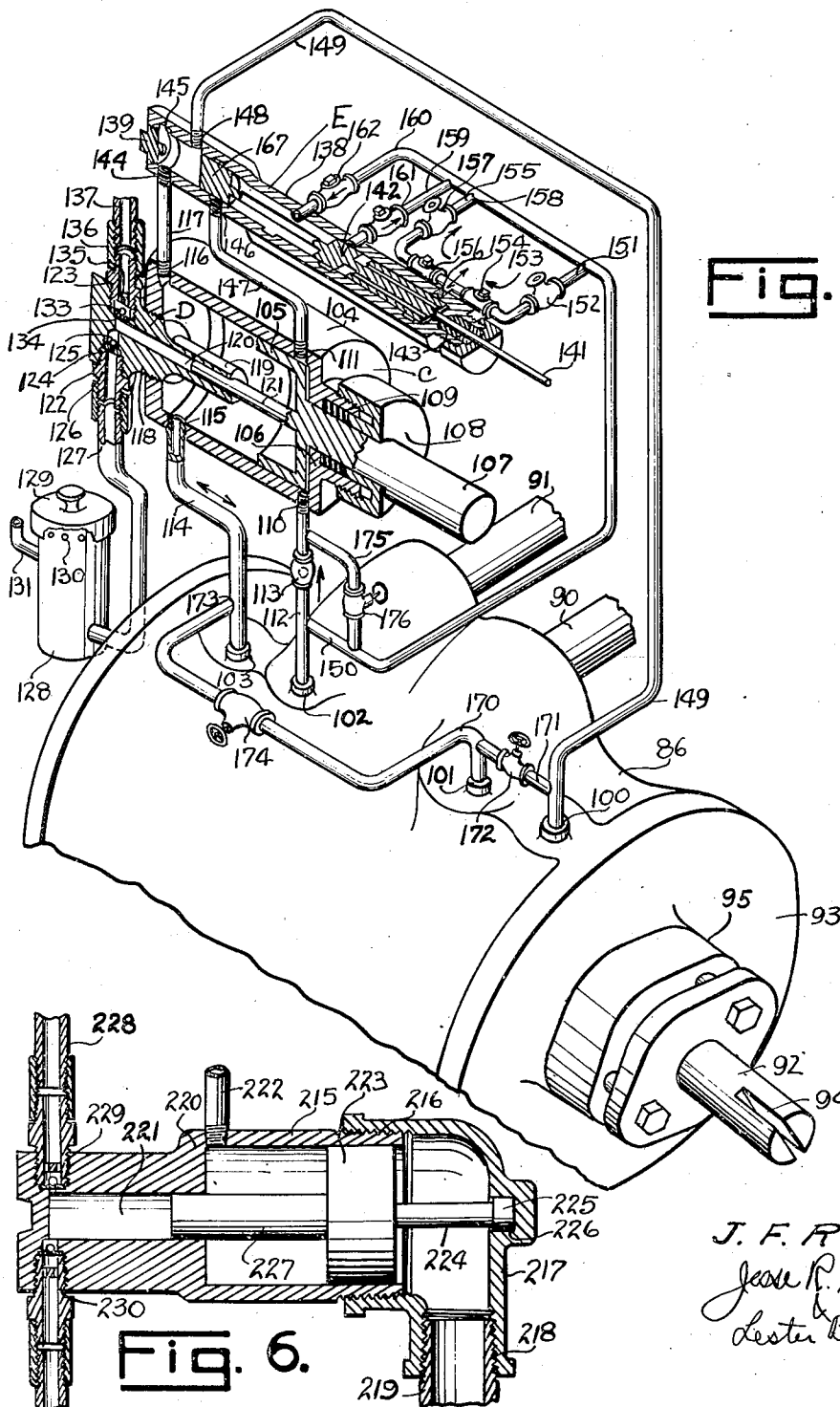
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9 Sheets-Sheet 5

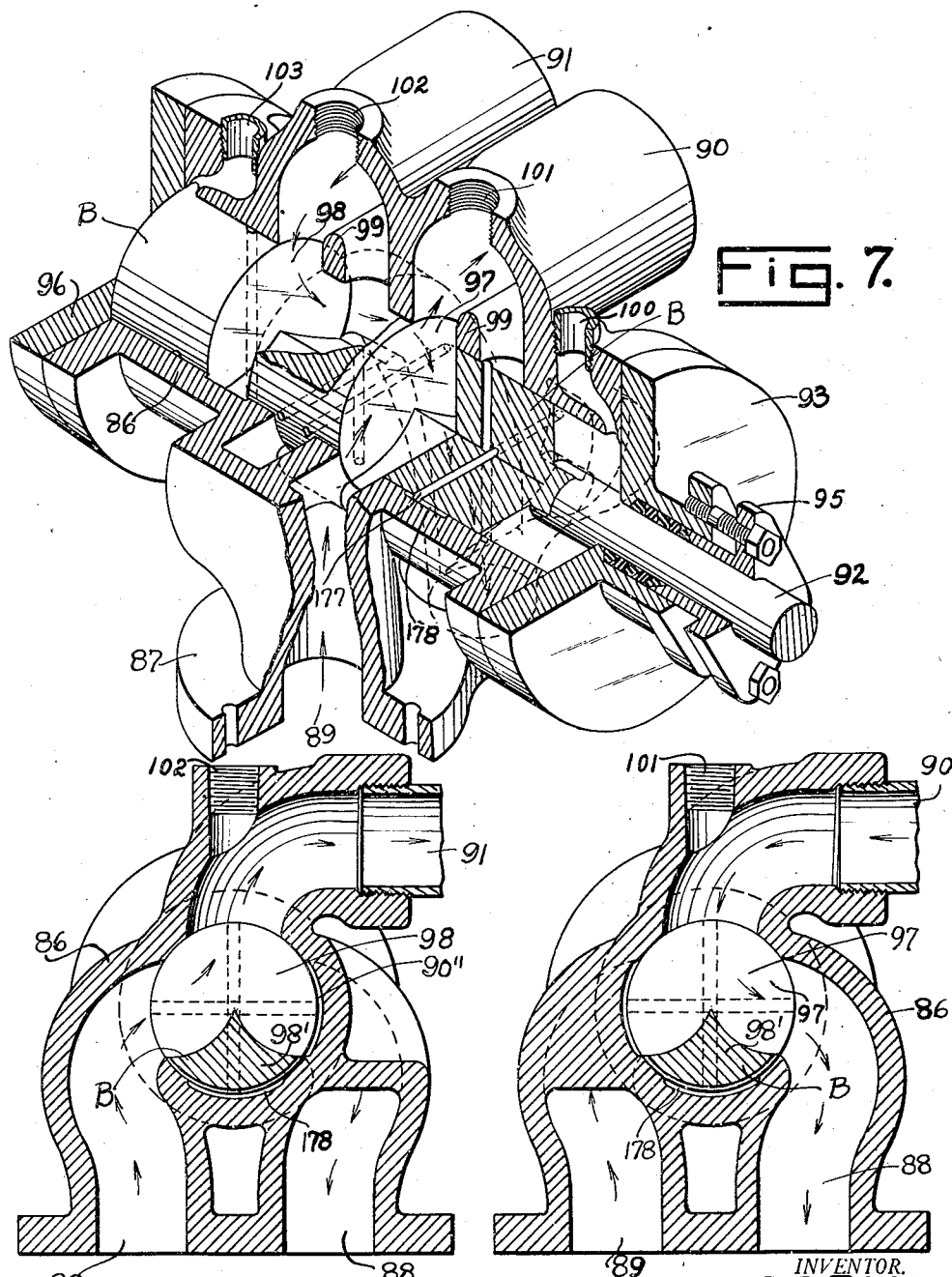


Fig. 8.

Fig. 9

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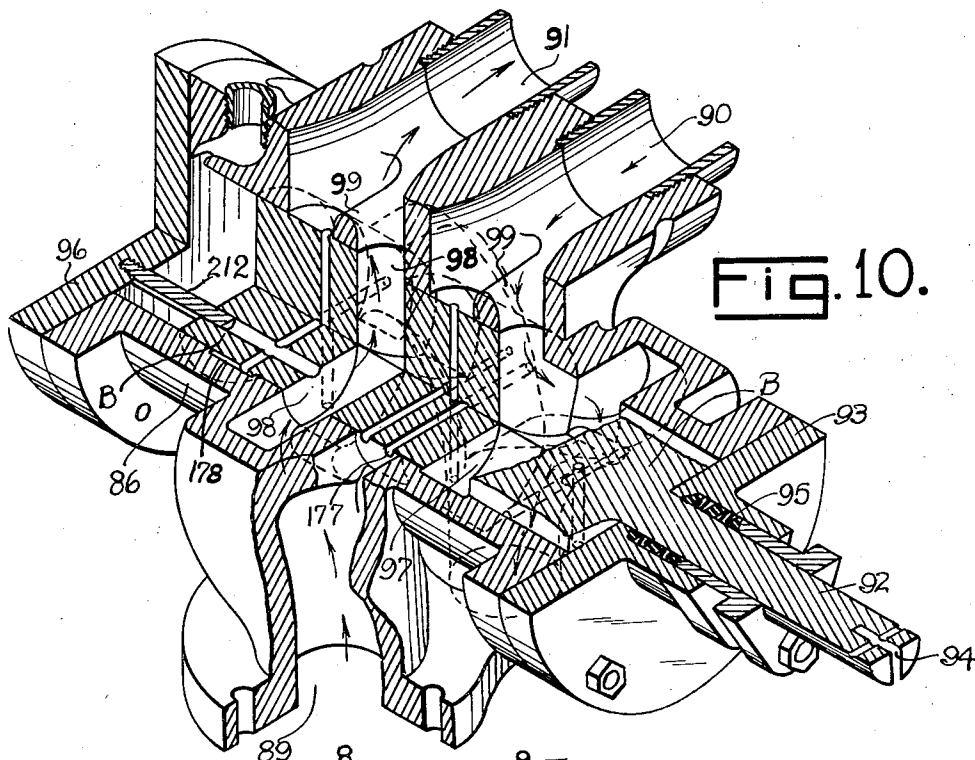


Fig. 10.

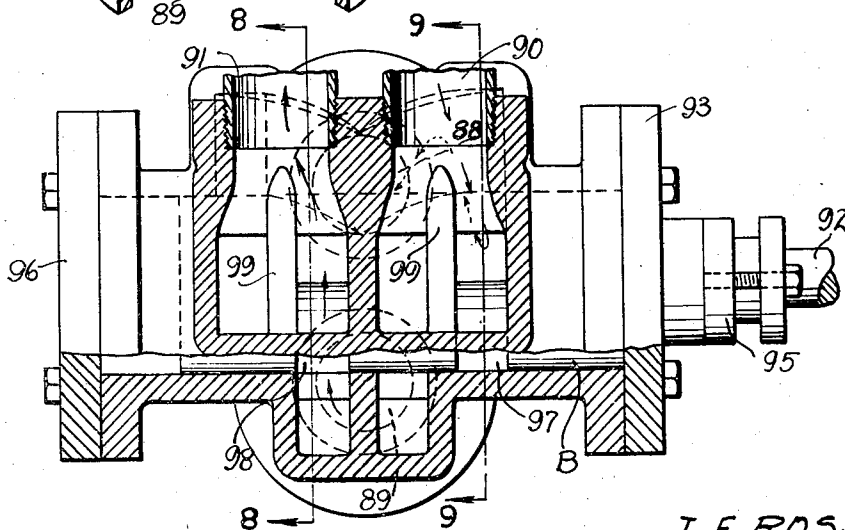


Fig. 11.

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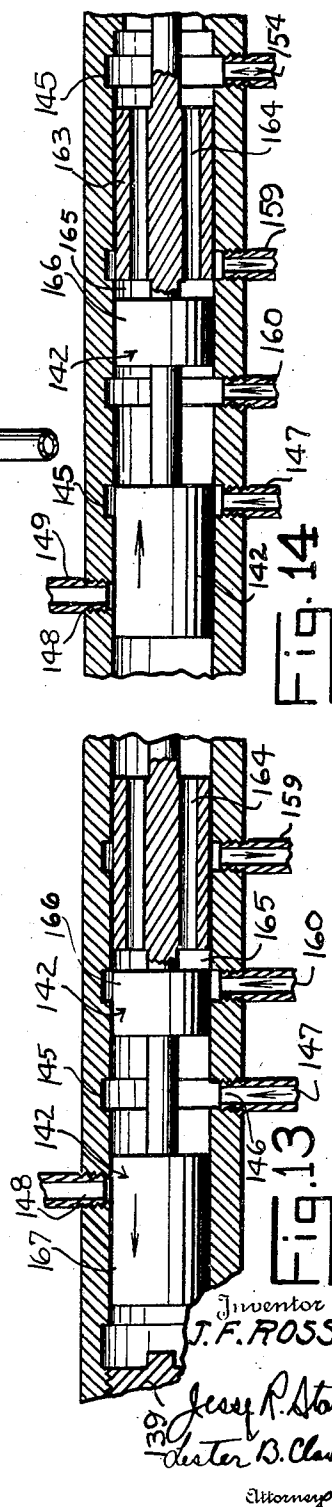
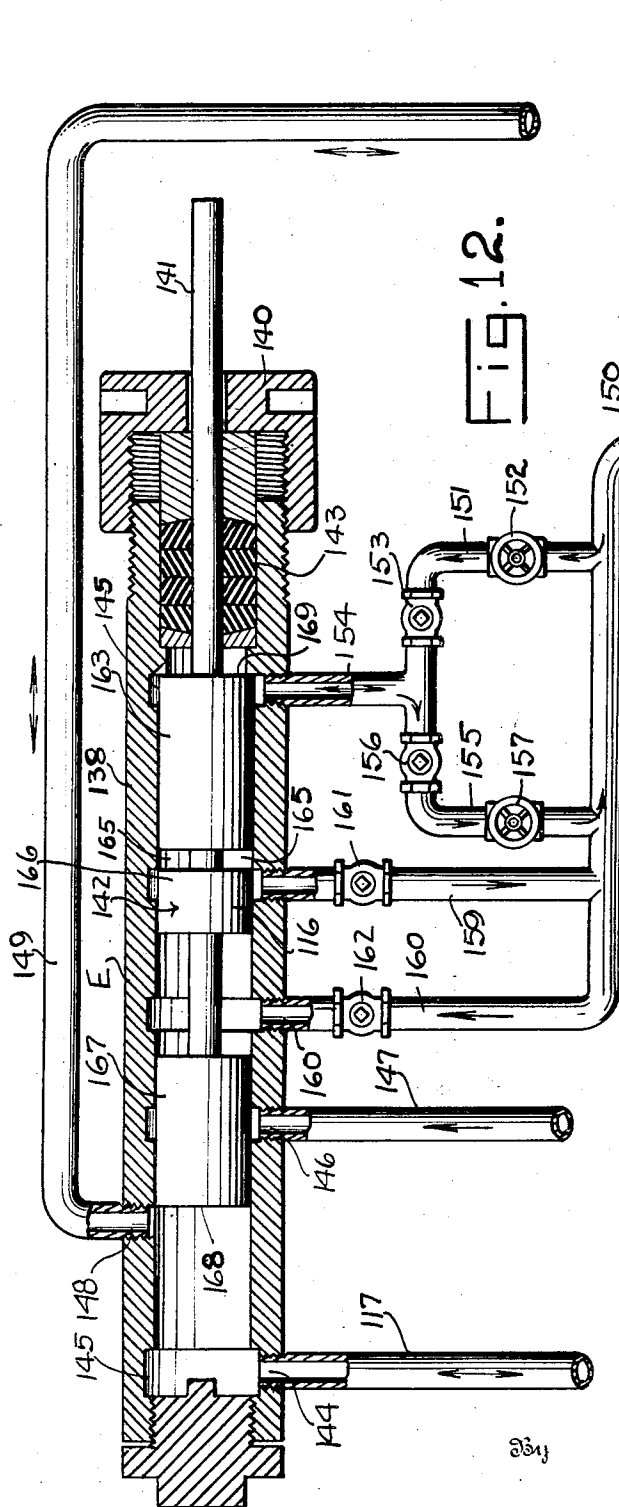
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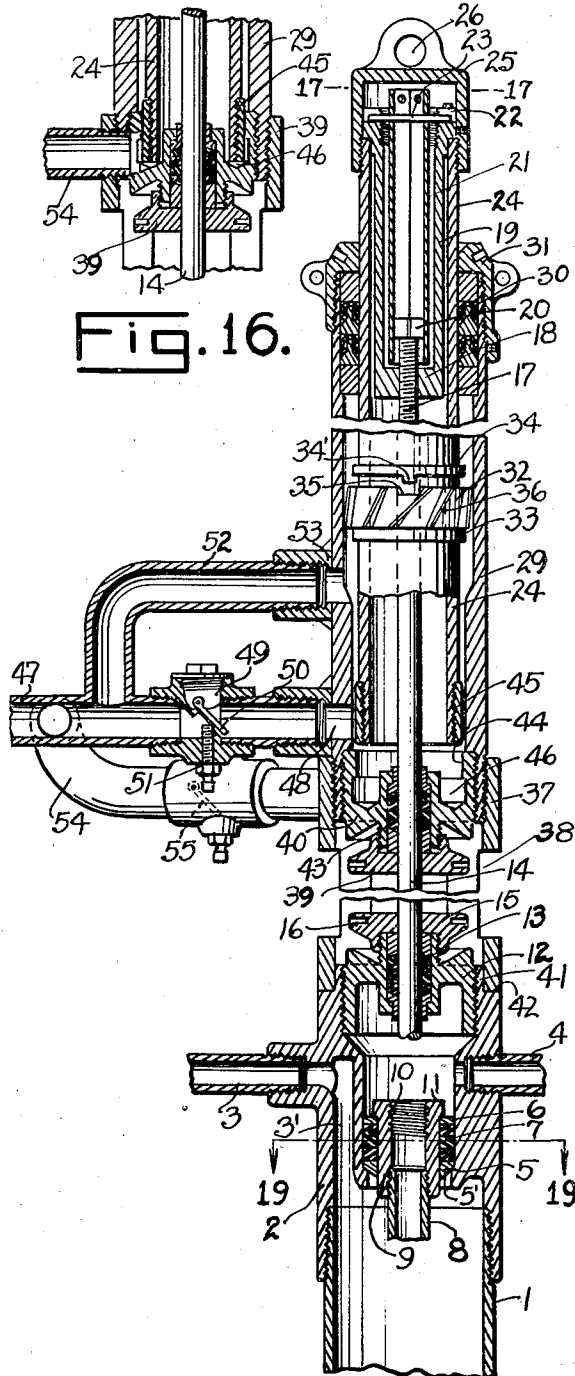


Fig. 15.

Fig.

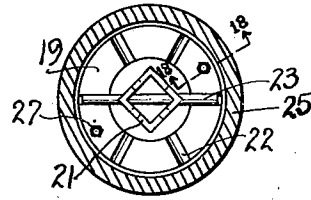


Fig. 17.

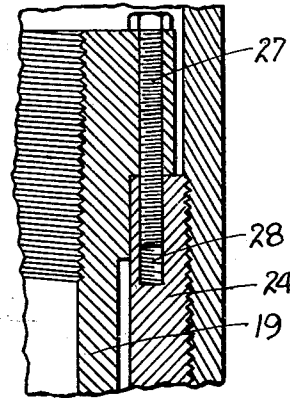


Fig. 18.

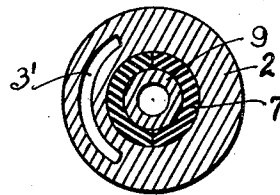


Fig. 19.

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SYSTEM OF PUMPING WELLS

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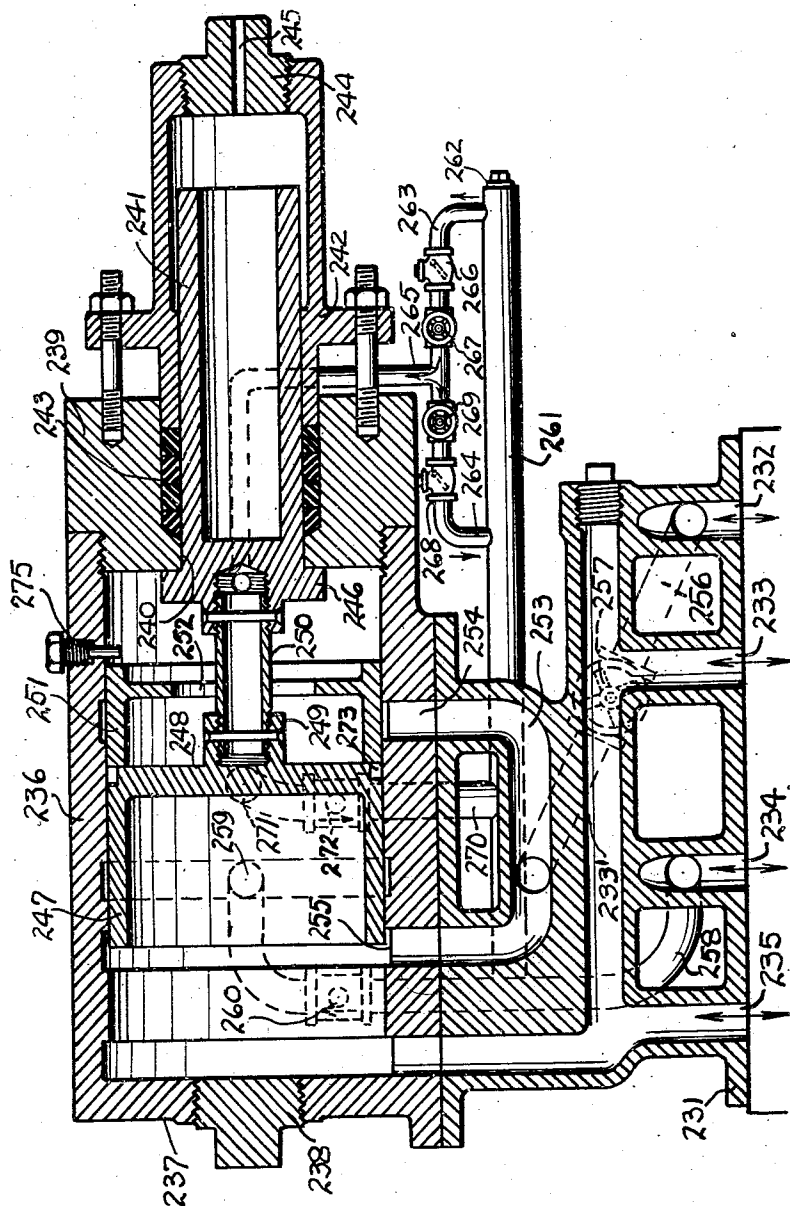


FIG. 20.

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UNITED STATES PATENT OFFICE

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SYSTEM OF PUMPING WELLS

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Application June 27, 1938, Serial No. 216,093

3 Claims. (Cl. 60—52)

This invention relates to a method and means of operating a fluid lift pump and particularly pertains to a method and means of operating, controlling, and counterbalancing the sucker rods and mechanism of a deep well reciprocating pump.

The present invention contemplates provision of pumping jack structure comprising a cylinder mounted upon a well and having a vertical reciprocating plunger therein, from which plunger sucker rods are suspended and extend down to the well pump. In modern deep oil wells for which this pumping system is particularly adapted, the sucker rods required frequently weigh many tons, and in this invention the rods are elevated by application of actuating fluid under pressure to the lower end of the pump jack plunger, said actuating fluid being stored in a pressure retentive fluid storage tank comprising an important element of this invention.

On each up or working stroke of such pump it is necessary to apply power to the pumping equipment in sufficient magnitude to simultaneously elevate the weight of the rods and pumping mechanism, together with the entire column of fluid being pumped, while on the down stroke no power is required as the weight of the rods suspended in the well causes their descent by gravitation alone. In fact, the gravitational downstroke of sucker rods and pumping mechanism develops such destructive force that their too rapid descent must be retarded and controlled by application of opposing weights or other counterbalancing means.

The intermittent high peak load and no load demand upon well pumping equipment and the great difference between the up and down stroke rod and fluid loads and momentive forces result in such a variable and unbalanced operating condition as to ordinarily require the installation within, or immediately adjacent to, the well derrick of extremely heavy cumbersome and costly pumping equipment to withstand the shocks and stresses incident to this work.

Important objects of this invention are: To provide a power transmission and control medium and means for automatically, safely and flexibly reciprocating, controlling, and counterbalancing the sucker rods and mechanism of deep oil well pumps, which said means may be, and preferably is installed and positioned remote from a well, thereby leaving the derrick floor space clear for other needed operations and at the same time safeguarding the equipment from the hazards of

fire, well blow-outs, falling derricks and the like inevitably existing in the vicinity of oil wells.

Other important objects of the present invention are to provide a means and medium adapted for reciprocating, controlling and counterbalancing the sucker rods and mechanism of deep well pumps. Said means and medium, without any disturbance to continuous pumping operations, may be manually manipulated at its location either near or remote from the well without need of skilled labor or use of tools, in a manner quickly and accurately to control and/or change the length of the pump stroke and to control and/or reverse the direction of the pump stroke and to regulate and/or adjust either upwardly or downwardly the vertical position of the pump jack plunger relative to its coacting cylinder and by so doing in like manner vertically regulate the interconnected well pump plunger relative to the well pump barrel within which it reciprocates.

It is well known to those skilled in well pumping that not only must counterbalancing equipment be provided for deep wells, but that the counterbalance should as effectively as possible tend to assist the power plant in elevating the weight of the rods and pumped fluid on the up stroke. Other important objects of this invention are: To automatically recover and store up for future use a material proportion of the energy and power developed by the weight of the gravitationally descending rods during each down stroke, and to apply this stored power towards assisting the motor in elevating the rods and pumped fluid on each upstroke. It is a further object to recover and store up and apply in a like manner the power output generated by the continuously running motor during the non-power consuming downstroke half of the pumping cycle, thereby attaining efficient, economical operation and insuring that the pumping operation will require only a relatively small continuously operating motive unit, consuming a minimum and substantially constant amount of horsepower. The energy and power so saved and conserved from said two forces during each down stroke is retained in the tank in the form of compressed actuating fluid, compressed air, for instance, and the expansive force of the compressed air is utilized and applied to assist the motor in elevating the rods and fluid load on each upstroke.

Other important objects of the invention are: To provide a unitized power driven well pumping plant which, while adapted for the operation control and counterbalancing of the reciprocable

elements of any single or individual well, is at the same time adapted for the like operation, control and counterbalancing of any number or multiple of wells from a centralized location. No changes or additions are required to said plant for the pumping of additional wells, except to regulate the pressure of the compressed fluid for counterbalancing purposes and to adjust the speed of the motor and the length of the pump strokes of the various wells to keep the aggregate power demand within the output capacity of the motor and plant. Means are also provided whereby the stroke lengths of the various wells may be controlled, that is made either longer or shorter, each independent of the other.

A still further object of the invention is: To provide economically constructed well pumping equipment embodying all of the elements of motivation, control and counterbalancing in one compact, lightweight, portable, centralized unit which is easily loaded and transported upon a truck, or which may be dragged from place to place upon the ground intact without injury. The complete pumping unit being assembled and ready at all times for instant use at any desired location, as no cement, sills, or other foundations are required for its installation and operation.

Another object of the invention is to provide in a vertically reciprocating fluid actuated well pump jack, means whereby the application of compressed fluid, such as compressed air, for instance, is automatically applied to check or retard the gravitational downstroke of the well pumping mechanism and sucker rods, thereby providing a flexible, compressible, cushioning medium to check the gravitational descent of said pumping elements.

I also aim to provide in a vertically reciprocating fluid actuated well pump jack, means whereby the application of substantially non-compressible fluid, oil for instance, is automatically applied to effect a stoppage of the down stroke travel of the well pump sucker rods and mechanism.

To provide in a vertically reciprocating fluid actuated well pump jack, means whereby the application of substantially non-compressible fluid—oil, for instance—is applied to check or retard the gravitational downstroke of well pumping mechanism and sucker rods, said means being provided with a manually operated adjustment.

Other objects include the provision of a rotary power driven pump and an effective type of reversing valve and power and bypass devices therefor which are automatically operated; and piping, valves, and connecting devices, all of which will be explained in connection with the drawings herewith.

In the drawings,

Fig. 1 is a side elevation of the power installation together with the valves and counter balancing devices employed with my invention, certain parts being broken away.

Fig. 2 is a diagrammatical plan view illustrating my device as connected with a plurality of wells.

Fig. 3 is a transverse section through one end of my fluid pressure tanks and illustrating the construction of my fluid reservoirs taken on the plane 3—3 of Fig. 2.

Fig. 4 is a view similar to Fig. 3 but showing a slightly different embodiment thereof.

Fig. 5 is a perspective view partly in central

longitudinal section illustrating the control valves employed in the operation of the fluid flow reversing valve employed in directing the fluid from the power pump to the jacks and from the power pump to the tank.

Fig. 6 is a longitudinal section through an air compressor which may be employed with the invention.

Fig. 7 is a perspective view partly in section illustrating the construction of my fluid flow reversing valve.

Figs. 8 and 9 are vertical sections taken on the planes 8—8 and 9—9, respectively, of Fig. 11.

Fig. 10 is a view similar to that shown in Fig. 7 but with the reversing valve in a different position.

Fig. 11 is a top plan view of the reversing valve partly in horizontal section.

Fig. 12 is a longitudinal section through my bypass valve and showing the valve at one end of its stroke.

Fig. 13 is a sectional detail illustrating the movement of the bypass valve toward one end of its stroke.

Fig. 14 is a similar sectional view illustrating the movement of the valve in the opposite direction.

Fig. 15 is a central vertical section through the pump jack which I prefer to employ.

Fig. 16 is a sectional detail showing the pump jack ram in its lowermost position.

Fig. 17 is a transverse section through the upper end of the ram on the line 17—17 of Fig. 15.

Fig. 18 is an enlarged detail in broken vertical section showing a portion of the ram taken approximately on the plane 18—18 of Fig. 17.

Fig. 19 is a transverse section through the casing head on the plane 19—19 of Fig. 15.

Fig. 20 is a central vertical section through a combined power valve and bypass valve, which is a modification of the structure shown in Fig. 5.

The hydraulically operated ram which I employ in reciprocating the sucker rod and plunger in deep well operations is disclosed best in Figs. 15 to 18, inclusive. In this view the upper end of the well casing 1 is shown as connected with a casing head 2, of a special construction. Said casing head has a lateral outlet from within the casing at 3 and an opposite outlet 4 which has connection with the tubing and may furnish an outlet for the liquid being pumped. Below the outlet 4 the wall of the casinghead is extended inwardly to form a supporting shoulder which is beveled inwardly, as shown at 5, to furnish a seat for a tubing hanger which includes a lower metallic ring 6' and upper metallic ring 6 with compressible packing rings 7 between them. As will be seen from Fig. 19 the rings are divided so that they can be inserted about or removed from around the hanger or tubing without disconnecting the hanger from the tubing.

The tubing 8 has at its upper end a hanger 9 which is threaded internally at its upper end at 10 for engagement with an upper section of tubing, lift nipple, or the like. The outer portion of the hanger is formed with a flange 11 thereon which is adapted to rest upon the ring 6 when the packing is in position. The weight of the tubing is thus suspended upon the packing installation and it is to be noted that the diameter of the hanger including the flange 11 is small enough so that the hanger may pass directly downward through the seat in the casing head when the packing installation is removed. It will be noted that the recess or slot 3' communicates from the

interior of the well casing to the outlet 3 from the casing.

The upper end of the casing head is closed by a plug 12 having a stuffing box 13 therein to fit about the pump rod 14, which is adapted to reciprocate therethrough. The packing within the stuffing box may be compressed through a cap 15, which is screwed over the upper end of the stuffing box and adapted to be adjusted through a wrench engaging within radial openings 16 in the cap.

The tubing hanger which has been described has certain advantages which will be obvious. When it is desired to move the tubing up and down as may be necessary in releasing the tubing from sand packed around the lower end, this may be done by engaging a lift nipple within the threaded upper end 10 and exerting an upward pull sufficient to bring the hanger above the casing head so that access may be had to the packing installation. This packing assembly will then be removed and thereafter the hanger may be moved up or down through the opening in the casing head through the seat 5. When it is desired to again hang the tubing the packing will be inserted and the tubing lowered again into position.

The sucker rod 14 has its upper end threaded at 17 to engage within the lower end 18 of the adjusting sleeve 19, which forms a portion of the ram member of the pump jack. Above the lower end 18 of the adjusting sleeve through which the threaded upper end of the pump rod engages, the pump rod is formed with a head 20 which is polygonal to engage within a polygonal sleeve 21 secured at its upper end to the adjusting sleeve. To form a connection between the two sleeves opposite notches 22 are formed in the upper end of the adjusting sleeve and a transverse pin 23 is engaged through openings in the polygonal sleeve 21 thereby fixing the two sleeves against relative rotation.

As the polygonal sleeve is nonrotatable relative to the sucker rod through the engagement of the sleeve with the head 20 on the rod the adjusting sleeve is also ordinarily non-rotatable relative to the sucker rod. The upper end of the adjusting sleeve is formed with a laterally extending flange which engages above the upper end of the body 24 of the ram. A cap member 25 is fitted over the upper end of the ram together with the adjusting sleeve, serving to close the ram at the upper end and to furnish attachment to a lifting device by means of the eyelet 26 in the cap.

The adjusting sleeve may be connected with the upper end of the ram body 24 by a set screw 27, as shown in Fig. 18. Said set screw may be threaded through the flange at the upper end of the adjusting sleeve and into a threaded recess 28 in the ram body, thereby fixing the two parts against relative movement.

The outer surface of the ram body is cylindrical and fits slidably within a cylinder 29. Said cylinder has an internal diameter considerably larger than the outer diameter of the ram body 24. At the upper end of the cylinder, however, I provide a stuffing box which forms a fluid tight fit around the ram. This stuffing box is preferably formed by a plurality of packing rings or cups 30 fitting between the upper end of the cylinder and the ram and held rigidly in position by means of a cap member 31. This stuffing box serves to close the upper end of the cylinder around the ram and form a tight seal between the two.

Near the lower end of the ram I provide a rotatable ring or collar 32, which normally rests upon a flange 33 upon the ram. Spaced rigidly above the ring on the body of the ram is a stop flange 34, which has thereon one or more downwardly extending lugs 34' adapted to engage within recesses 35 in the upper end of the ring 32. On the outer surface of the ring I provide inclined or spiral blades 36 positioned in such manner as to rotate the same in a right-hand direction on the downward stroke of the ram. It will thus be seen that on the upward stroke of the ram the rotating sleeve 32 rests upon the flange 33 and has no effect whatever upon the ram. On the downward stroke, however, the lugs 34' will engage within recesses 35 and the rotation of the ring 32 will tend to rotate the ram in a righthand direction and thus tend to rotate the sucker rod also and tighten the joints in the rod during the down stroke. The ring or collar 32 could obviously be formed with spiral grooves therein, which serve the same function as the blades previously maintained.

The cylinder 29 is connected at its lower end within a sub or cage member 37. Said cage member has openings 38 therein adjacent the cap 15 previously referred to and to a similar cap 39 on a plug 40, which closes the lower end of the said cylinder 29. The cage member 37 fits closely at its lower end around the reduced upper end 41 of the casing head. It bears upon the shoulder 42 on the casing head and is rigidly maintained in that position by the weight of the cylinder and the ram, and its load.

The plug 40 which closes the lower end of the cylinder 29 has a stuffing box 43 which forms a sealing fit about the sucker rod. The cap 39 previously mentioned tends to hold the packing in such stuffing box tightly compressed about the rod. The upper end of the plug 40 is recessed around the stuffing box to provide an inner wall 44 which engages close against the outer surface of a ring 45 fixed upon the lower end of the ram. Thus when the ring 45 engages therein the escape of fluid below the ram from the cylinder is substantially cut off. There is a further recess or undercut chamber 46 in the plug 40 below the surface 44 into which the ring 45 may descend as shown in Fig. 16.

The pressure fluid which raises the ram may enter the cylinder through a pipe 47 coming from a source of pressure fluid which will be later described. It may enter the cylinder through an opening 48 therein by way of a check valve 49. Said check valve is of ordinary construction and includes a flap valve 50, or any other adjustable valve, which opens inwardly toward the cylinder. My valve has, however, an adjusting screw 51, which is threaded through the lower wall of the valve body and engages the valve member 50. This screw may be adjusted to prevent the complete closing of the valve and may hold the valve open to the desired extent to limit the outward flow of fluid on the down stroke of the ram. There is a bypass 52 from the cylinder and around the valve 49 to the pipe 47 through which fluid freely passes from the cylinder during the down stroke of the ram.

I also provide a connection with the cylinder from the pipe 47 through a branch pipe 54. Said branch leads from the pipe 47 to connect with the cylinder at a level slightly below the opening 48. There is a check valve 55 in this line, which is normally adjusted to close completely against the escape of fluid outwardly from the cylinder, but

same may be adjusted by a screw similar to valve 40.

It will be obvious that when pressure fluid is discharged towards the cylinder through the pipe 47 it may enter the cylinder through any of the three pipes which have been shown. It will gain entrance below the ram even at its lowest level by way of the pipe 54 so as to start the ram on its upward movement. It may also find entrance through either of the other pipes during the lifting of the load. When the upward stroke has been completed and the pressure relieved below the ram, the weight of the rods, ram, and the pump plunger causes the ram to drop and as the lower end of the ram passes the opening 53 the lateral escape of fluid from below the ram may be checked as gradually or as suddenly as desired by regulation of the valves 40 and 55. No fluid may escape thru the valve 55 when normally adjusted and the amount escaping upwardly within the cylinder past the ring 45 is so small as to prevent the ram from landing violently on the plug 40. Thus the dropping of the ram will be checked and before completion of the downward stroke a new charge of pressure fluid can be forced through the pipes into the cylinder to further resist the falling of the ram at the lower end of the stroke. While the check valve 55 is normally adapted to close completely, conditions arise, particularly with high speed or heavy rod loads, where it is desirable to slightly open check valve 55 to more gradually cushion the hydraulic shocks occasioned by said high speeds or heavy loads.

It will also be noted that if the ring 45 at the lower end of the ram passes the port 48 it will engage automatically within the opening 44 in the lower plug 40 and encounter the liquid normally trapped within the lower end of the cylinder and more positively check the descent of the ram.

The threaded adjusting sleeve 19 is employed in adjusting the vertical position of the well pump plunger. In pumping operations, the length of the pump rods must be adjusted with a fair degree of accuracy so that the pump plunger will reciprocate at the proper place in the pump barrel. The rods stretch a material amount due to the load thereon, and allowance must be made for such change in the length. To adjust the rod, for example, the cap 25 is removed, the pin 23 and the squared sleeve 21 are then removed. This allows rotation of the sleeve 19 together with the interconnected ram relative to the sucker rod, which rod 14 is supported by engaging a rod clamp about the said rod below the stuffing box cap 39 and resting upon cap 16 after the rod has been raised to the desired height.

Rotation of the adjusting sleeve and ram in the proper direction will screw it upwardly or downwardly on the rod until the desired setting is obtained. The parts which were removed may be then assembled as before, the rod clamps removed, and the pumping may proceed.

The fluid under pressure which tends to raise the ram and its load of liquid is provided initially through a power pump which may be driven from any desired source of power. In Fig. 1 this pump, which may be shown generally at A, is of the rotary type and adapted to be actuated through a belt or chain connection 56 with a motor 57, which may be an internal combustion motor, if desired.

To direct the flow of fluid from the storage tank to the pumping jack and from the pumping jack to the fluid storage tank at the proper time, a fluid-flow reversing valve is placed immediately above the pump. In Figs. 7 to 11, inclusive, the

structure of my reversing valve may be seen. Said valve is constructed with an outer housing 86 which has a generally cylindrical contour. For connection with the pump said housing has a downward projection thereon. Said projection is flanged at 87 to seat upon the upper surface 50 of the pump case. There are two downwardly presented openings 88 and 89 adapted to register with openings of the pump A and through which fluid flows to and from the pump. At the upper end of the housing there are two laterally extending openings 90 and 91 through which fluid may flow from the fluid-flow reversing valve to and from the pumping jacks and tank. The flow into and from the rotary pump past the reversing valve is controlled by an inner reciprocating plunger member, which may be designated generally at B. This plunger fits within a cylindrical chamber on the interior of the housing and is adapted to be reciprocated longitudinally in the housing.

The plunger B has at one end thereof an axially extending stem 92. Said stem extends through the outer end of head 93 of the housing and has its end slotted, as shown at 94, so that the movement of the valve may be manually controlled by a lever inserted within the slot when desired. A seal is formed about the projecting stem 92 by means of the stuffing box 95. The opposite end of the valve housing is closed by a head 96. The body of the plunger is formed with spaced slots or passageways 97 and 98. As will be seen from Figs. 7 to 11, said slots do not extend entirely through the plunger body but the lower sides of the slots are substantially closed by portions of the plunger body indicated at 99, which are curved downwardly from a central line to direct fluid in either direction from the upper side as will be obvious from these figures.

It will also be noted that the passages 90 and 91 are branched on the inside of the housing so that the flow may be directed in either of two directions by means of dividing plates 93, forming a portion of the wall of the housing and fitting on their inner surfaces closely against the body of the plunger. It will be understood that when the plunger is moved to bring the slots or passages 97 and 98 therein to one side of the adjacent dividing plate 93 the fluid may flow in one direction and when it is moved to the opposite side of the dividing plate the fluid may flow in the opposite direction.

In the position of the valve shown in Fig. 10 fluid passing the dividing plate and entering the slot 97 in the plunger body will be directed laterally toward the passage 88 leading to the pump intake. When the plunger is in one position the branch opening at one side of the slot 97 will be closed and the other open as seen in both Figs. 8 and 9. When, however, the plunger is moved longitudinally to bring the slots 97 or 98 to the opposite side of the dividing member 93 the fluid may flow in the opposite direction. It will be understood, therefore, that when the plunger member B is moved toward the end plate 93 the fluid entering through the opening 90 will be directed downwardly to the inlet opening 88 of the pump and the slot 98 will be brought into position to allow the passage from the discharge side of the pump upwardly and out through the opening 91. When the plunger is in the opposite position, as shown in Fig. 7, the positions of the slots relative to the separating members 93 will be reversed and the passage of fluid to and from the pump through the valve will also be reversed. This plunger B is adapted to be moved from one end to the other of its stroke by means controlled

automatically in the operation of the system. This control means will now be described.

Referring to Fig. 5, it will be noted that the housing 86 of the fluid-flow reversing valve is formed with a plurality of ports therein. At one end of the housing are two ports 100 and 101. Near the opposite end of the housing are two ports 102 and 103. Fluid passing to and from the housing of the reversing valve passes in and out through these ports in a manner which will be described.

Adjacent the housing of the fluid-flow reversing valve is a power valve shown generally at C. I have shown this valve spaced directly above the reversing valve although it may be placed in any convenient position. Said power valve comprises a cylindrical shaped body 104. Within the body is placed a plunger 105. This body is closed at one end by the end plate 106 and the body of the plunger movable therein is open on the side away from the said closed end. Projecting outwardly from the end of the plunger is a stem 107 which projects beyond the end of the stuffing box 109 formed in the end plate 106 and leaves the end of the said stem exposed to atmosphere. The end plate 106 of the valve body 104 is closed about the stem by the stuffing box including the cap 108 and the packing 109.

There are lateral ports in the wall of the valve body 104; one port 110 is at the lower side adjacent the end of the plunger member 105. Opposite this port and on the upper side of the body is a port 111. The valve is so formed that fluid passing into the valve body through the port 110 may pass between the end of the plunger and the end wall of the body and flow through the port 111. The port 110 is connected with the port 102 in the reversing valve housing by the pipe 112, said pipe having therein a check valve 113 opening in the direction of the arrow adjacent thereto. Said pipe 112 intercommunicates with the pipe 91 connecting the reverse valve to the jack and at all times the fluid pressures in pipes 112, 91 are therefore equal. Also, it will be noted that the pipe 170 intercommunicates with the pipe 90. Therefore, the fluid pressures in pipe 170 and pipe 90 are likewise equal.

At the left end of the valve body a pipe 114 connected with the port 103 in the reversing valve is extended through the wall of the body 104 at 115. There is an upper outlet from the housing 104 at 116 in which is secured the pipe 117. This end of the valve is also so formed that irrespective of the position of the plunger 105 a free flow of fluid is possible in either direction through the pipes 114, 117.

In connection with this power valve I may include an air compressor or pump shown generally at D. This compressor, which is adapted for the pumping of liquid as well as for the compression of air, includes a body 118, which is screwed within an opening in the end of the valve body 104. Said compressor body projects into the interior of the power valve body and has an extension 119 formed with an axial bore 120 within which the compressor plunger 121 upon the valve member is adapted to reciprocate. The outer end of the body 118 of the compressor has a lower port 122 and an upper port 123, said ports being connected with the end of the bore or cylinder 120 of the compressor. The lower port 122 is the inlet port. It has a disc 124 therein with a central passage therethrough, the upper portion of which forms a seat for the ball valve 125. Said ball valve is

held in its seat by gravity. The said plate 124 is held in position by a fitting 126, which is screwed within the port 122 and serves as an attachment with the pipe 127, which may be connected with a container 128, the upper end of which is closed by a cap 129. This cap shields minute lateral openings 130 in the upper portion of the container wall which, while allowing admission of air, serves to prevent the entrance of insects or other foreign matter. There is a lateral pipe 131 formed in the container which is connected with the liquid tank, as will be later described.

The upper port 123 has a valve 133 fitting upon a seat 134 in the same manner as the lower valve. There is a perforated disc 135 above the valve 133 which limits its movement upwardly. A fitting 136 screwed within the port 123 retains the seat plate 134 in position. Said fitting forms a connection with a pipe 137 which conveys pumped fluid from the compressor to the fluid storage tank which will be later described.

Movement of the power valve plunger 105 to the left is caused by application through pipes 91, 112, through port 110 to the right end of the plunger, of fluid from the power pump at pressure sufficient to overcome friction between the plunger and its cylinder, and to overcome the resistance offered by the fluid at tank pressure on the left end of said plunger. The desired power-applying function of plunger 105, which occurs during its movement back to the right, forces fluid out of port 111 and on through pipes 147, 149, at pressure sufficient to aid or complete the leftward stroke of the reversing plunger B, which moves leftward because the force of the fluid at tank pressure, which always exists at the left end of plunger B, is much less than the force exerted on the left end of the power plunger 105. Therefore, when proper fluid communication is provided the plunger 105 moves rapidly to the right and performs its power applying function of moving the plunger B to the left.

Adjacent the power valve body 104 in any convenient position I provide a fluid bypass valve shown generally at E which could as well be designated as a pilot or timing valve. Said valve comprises a cylindrical case 138, said case being closed at one end by the plug 139 and at the other end is formed a stuffing box 140 through which projects a stem 141 extending from a compound plunger member 142. There is a stuffing box 143, which forms a seal about the stem 141, and allows the reciprocating of the stem there-through. The end of the stem 141 is exposed to atmosphere.

The valve case 138 is formed with fluid ports therein through which connections are made with other portions of the apparatus previously described or to be described. At the end of the housing adjacent the plug 139 the pipe 117 is connected to a port 144, thus allowing the passage of fluid through said port into a slight recess 145 in the valve case 138. Spaced from the port 144 is another port 146 into which is connected a pipe 147 which leads to the port 111 in the power valve previously noted. Between the ports 144 and 146 and preferably on the opposite side of the valve case is the port 148, from which pipe 149 leads to the port 100 in the reversing valve housing 86.

Connected in the pipe 112, which has been previously described, is a pipe 150, which leads from below the check valve in the pipe 112 upwardly adjacent the bypass valve E and is con-

nected to said bypass valve by a plurality of pipe connections which may now be noted.

There is a branch of said pipe 156 at 151 leading by way of a hand operated valve 152 and an inlet check 153 to a pipe 154 connected through the wall of the case 138 adjacent the righthand end of the said case. The pipe 154 also has an outlet branch therefrom, said outlet including a pipe 155 having therein an outlet check valve 156 and a hand operated valve 157. The said pipe 155 is connected with the pipe 158, as shown at 158. Said hand-operated valves are hereinafter designated as jack stroke timing valves and their purpose and operation will be hereinafter set out.

The pipe 158 is extended beyond the pipe 151 and 155 and is connected through the wall of the housing 138 by pipes 159 and 160. The pipe 159 has therein a check valve 161 and the pipe 160 has a check valve 162. The valve 161 allows an exit of fluid from the case 138 while the valve 162 allows the entrance of fluid thereinto.

The bypass plunger is constructed as best seen in Figs. 12 to 14, inclusive. Said plunger includes a piston-like member 163, which is formed on the stem 141 and is initially positioned toward the end of the case 138 adjacent the stuffing box 143. This piston is slightly elongated and has fluid passages 164 longitudinally thereof, as will be noted from Figs. 13 and 14. Spaced slightly from the piston 163 by the annular groove 165 is a shorter piston 166 and beyond this piston the stem is extended to connect with the piston 167 adjacent the left-hand end of the housing near the plug 139.

The inner wall of the bypass case 138 is provided with an annular recess adjacent each of the ports with which the pipes 154, 159, 160, 147 and 117 are connected. This will be clear from Fig. 12. These recesses prevent lateral hydraulic thrust upon the body of the plunger by equalizing same on opposite sides of the plunger, thereby leaving only friction to be overcome in moving the plunger. It will be understood from the construction of the bypass plunger that the end pressures which may be exerted upon same are unbalanced due to the fact that the end indicated at 168 of the plunger is of greater area than the opposite end at 169 due to the formation upon the end 169 of the stem 141 projecting through the end of the valve housing and exposed to the atmosphere.

Referring further to Fig. 5, it will be seen that the pipe 149 is connected to a pipe 170 by means of a cross connecting pipe 171, said pipe having therein a handoperated valve 172, the purpose of this cross connecting pipe 171 and valve 172 being to permit intercommunication of fluid between opposite ends of the fluid-flow reverse valve plunger B, when it is desired to manually or otherwise move the plunger B by means not associated with its automatic reciprocation. Said valve 172 is always closed during automatic operation of the reversing mechanism. The pipe 170 is connected into the port 181 wherein the pressure of the actuating fluid in the tank is always existent and the pipe 170 has connection at its other end at 173 to the pipe 114, which thereby necessarily is likewise always at tank pressure, which said tank pressure extends upwardly and downwardly through the pipe 114 to the lefthand end of the plunger in the reversing valve as well as to the plungers in the power valve and in the bypass valve.

I have in the connecting pipe 170 a hand-op-

erated valve 174, which normally remains open during automatic operation of the system but which may be closed as required to regulate or adjust the vertical position of the ram relative to its cylinder and thereby correspondingly adjust the vertical position of the well pump plunger relative to the well pump barrel. It will also be noted that the pipe 158 has connection with the pipe 112 on the upper side of the check valve 113 by a cross connecting pipe 175, said pipe having a hand-operated valve 176 therein, and the purpose of said cross connecting pipe 175 and valve 176 is as follows:

Normally the valve 176 remains closed during operations, and further, during operations, the plunger 185 of the power valve C normally performs its power applying function and ceases movement when it has traveled but a limited proportion of its possible lateral movement, and in the event said limited travel of the plunger 185 fails to provide the air compressor interconnected to said plunger with the required length of compressor stroke said valve 176 is then left slightly opened to permit fluid leakage through the valve 176 out from behind the righthand end of the plunger into pipe 158 to cause a longer stroke of same, and thereby increase the compressor stroke. The regulation of the vertical position of the ram and the well pump plunger suspended therefrom, relative to their respective cylinders, by operation of the hand valve 174 is illustrated as follows: Assuming for instance that the maximum ram or well pump plunger travel is seven feet, and assuming further that the pumping of a given well requires only a two foot stroke, and that the timing valves 152, 157, permitting travel of the bypass plunger 142 to cause reversal of the pump jack strokes are timed for a two-foot stroke, and that said two foot stroke is occurring adjacent the extreme lower end of the pump jack cylinder and of the interconnected well pump cylinder and that because of wearing of the well pump cylinder, or elongating of the sucker rods, or for other reasons it is desired to have said plunger perform its said two foot stroke in any upper or higher portion of said cylinder, then and in that event, during the up-stroke of the ram said valve 174 is manually closed during which closure stroke reversal is impossible as fluid must pass through said valve 174 during the occurrence of both the up and the down stroke, after closure of valve 174 and when the ram has reached the maximum height of its new or desired up-stroke position, which may be at any point desired, the valve 174 is quickly reopened. Whereupon automatic reverse now immediately occurs and the ram descends its original two-foot stroke distance for which the timing valve 157 had all the time been set, upon the completion of said two foot downstroke the upstroke reverse again automatically occurs, and we now have the well pump plunger performing its desired two foot stroke in a new place in the well pump barrel. It will thus be seen that by manipulation of valve 174 the well pump plunger may, without any disturbance to continuous pumping, be raised or lowered within its co-acting cylinder to any desired position.

The pressure of the tank fluid in the system which is always exerted against the plungers B, 105 and 142 will move the plungers in a righthand direction so that in upstroke-starting position they will stand in the position shown in Fig. 5 and Fig. 10. This is due to the fact that the area exposed to fluid pressure is greater on the

lefthand ends of these valve plungers because of the greater area exposed to the pressure on that end.

With the valves in this position the pump is started. The position of the reversing valve B will then be as shown in Fig. 10. The port 90 will be the inlet port in the reversing valve and pump and will be connected with the storage tank. The discharge port 91 is connected through the slot or passage 98 with the outlet or discharge end of the pump.

The pressure of the fluid in the discharge pipe 91 of the reversing valve will be exerted outwardly through the pipe 112 but will be prevented from entering into the bypass valve at 146 by the position of the plunger 167 therein. Tank pressures will, meanwhile, be exerted through the pipe 114 through the power valve member 104 and the pipe 117 to the lefthand end of the bypass valve, thence outwardly therefrom through the pipe 149 to the port 100 in the reversing valve. Although the pressure of the pumped fluid cannot pass through pipe 112 into the housing E of the bypass valve, the pressure entering the power valve through the port 110 will move the power valve plunger 105 to the left of its position shown in Fig. 5 and in doing so will force the plunger 121 to drive the air in the compressor cylinder 120 outwardly past the valve 133. During all the up-stroke of the pumping jack the power valve plunger 105 will remain in an extreme lefthand position where its further progress is limited by impingement of the compressor piston 121 against the lefthand end of the compressor cylinder 120 in which position all fluid or liquid, as the case may be, has been forced out of the compressor cylinder 120 past the discharge valve 133 into pipe 137. With the reversing valve in the aforesaid up-stroke position the pressure of the pumped actuating fluid will pass through the port 91 to enter the cylinder 29 of the jack under the ram 24 and perform the up-stroke of the jack. Said pumped fluid pressure at the same time passes from port 91 into the pipes 112, 150 and on to the fluid inlets 151, 160 for the purposes herein-after fully described. Tank pressure meanwhile is maintained at both ends of the reversing valve plunger by fluid communication with the tank through ports 100, 101, 103 and pipes 149, 170, 114 and 117, respectively.

The tank pressures upon opposite ends of the valve plunger B within the reversing valve housing will therefore be such as to hold the plunger in the position shown in Fig. 10 due to the greater area exposed to pressure on the end of the plunger remote from the stem 92. In this connection it may be noted that the plunger B of the reversing valve is hydraulically balanced laterally by the provision through the body of the plunger of passages 177, which allows the passage of pressure fluid transversely through the body of the plunger and allows the balancing of pressure on both sides thereof. To further assist in balancing the pressure at the periphery of the valve plunger the inner wall of the housing may be recessed as shown at 178 where it is necessary that the pressure be balanced. These provisions for preventing lateral hydraulic thrust upon the body of the valve plunger B leaves only the ordinary friction as resisting the movement of the valve plunger. To provide against rotation of the plunger B in its housing, a pin 212, one end of which is rigidly fixed in the head 96 of the reverse valve, is employed. Said pin fits a lon-

gitudinal bore through the lefthand head of the plunger as shown in Fig. 10.

It is to be noted that the pipe 91 of the reversing valve 90 is open through the port 102 and pumped pressure fluid may pass therefrom through the pipe 150 around to the pipe 151 and into the port 160 in the bypass valve, but the fluid entering port 160 between the opposing pistons 166, 167 has no effect on same, as being of equal area they are thus hydraulically balanced. By regulating the position of the inlet valve 152 the amount of fluid which may enter the bypass cylinder may be limited to the desired amount to time the movement of the bypass plunger, so as to control the movement of the reversing plunger, B, to coincide with any desired jack stroke length. Fluid passing the valve 152 and the check valve 153 will enter the housing 138 at the end thereof, as indicated particularly in Fig. 12.

When the bypass plunger reaches the left end of its throw and the piston 167 has passed to the left of port 148, pumped pressure fluid will pass from pipe 91 through pipes 112, 147 and 149 whence it will enter the reversing valve housing 86 through the port 100 in the housing and engage behind the right hand end of the reversing valve plunger B. As the pressure of this fluid from the pressure side of the pump is sufficiently great to overbalance the tank pressure at the other end of the valve plunger B, said plunger will start movement toward its opposite position. As it is moved longitudinally in the valve housing the slot 97 and the slot 98 will reach an intermediate or neutral position where the pressure in the entire system, except in the righthand end of the power valve 105 and the pipe 147, casing E, pipe 149 and the right hand end of the reversing valve, will be equal and the reverse plunger will tend to stop. Further fluid, however, is discharged into the end of the housing 86 against the stem end of the reversing plunger at pressure sufficient to complete its movement to the lefthand end of the reverse valve housing. This further pressure fluid is obtained from the righthand end of the plunger 105 of the power valve C, the only outlet therefrom being through pipe 147 as the pipe 112 is closed by the check valve 113, also the hand operated valve 176 is normally closed though at times it may be partially opened to increase the length of the air compressor plunger stroke as herein more fully described.

It will be seen that the pressure fluid entering through the pipe 154 will engage against the end of the piston 163 and through the longitudinal fluid passages therein impinge against the surface of the piston 166. The pressure of the fluid on the piston 166 will move the entire plunger slowly, depending upon the rate said fluid may pass through the valve 152. At the proper time the piston 166 will approach the opening 160, as shown in Fig. 13, and continuing will open said port. As will be noted, the pipe 160 has a full open passage and as soon as the piston 166 slightly uncovers the port 160 the fluid pressure therefrom will be exerted against the plunger in full force and will immediately throw the piston portion 167 of the plunger assembly to the extreme left end of the cylinder 138 and fully open port 148 to provide free fluid communication between ports 148 and 146. Whereupon, high pressure pumped fluid from pipe 91 will pass to the righthand end of the reverse valve housing 86 and start leftward movement

of its plunger B, as heretofore described, the balance of the leftward travel of the plunger B being performed by the automatic action of the power valve mechanism as immediately hereafter explained.

In order to note this fact it will be understood that when the bypass valve has moved to its ultimate lefthand position and opens the passage between and through the pipes 147 and 149 the fluid in the cylinder 104 between the power valve plunger 106 and the righthand end 106 of the valve housing 104 will be forced out through the pipe 147, thence through the bypass valve body and through the pipe 149 down into the housing 86 of the reversing valve at the righthand end of the plunger B and exert sufficient force to cause said plunger to complete its movement to the left.

The reversing plunger will be moved backwardly to the original position by an action of the bypass valve which is practically the reverse of the original movement. It will be observed from the drawings that when the bypass plunger 167 is at the lefthand end of its stroke the pumped pressure fluid may pass through the valve housing E, through the pipes 147 and 149, but will not affect the movement of the bypass plunger due to the fact that the pressure is equal in both directions between the two pistons 166 and 167. Hence the pressure entering through the pipe 117 against the left end 166 of the valve plunger will move it to the right toward the position shown in Fig. 12. This movement in the opposite direction will be regulated by adjustment of the hand valve 157. This fluid may escape only through the outlet pipe 154 past the check valve 156. This hand-operated valve is so adjusted that the fluid will pass the same at a predetermined rate which will serve to time the movement and opening of the bypass valve. The bypass plunger will, therefore, be moved slowly to the right, due to the small outlet of the fluid through the valve 157 at the righthand end of the plunger. There will be a time, however, when the left end of the piston 163 of the plunger member will approach and finally uncover the pipe 159, which position of the approaching piston 163 is shown in Fig. 14 where the pipe 159 is just about to open, permitting a rapid flow of fluid from in front of the piston 166 through the outlet 159. This sudden relief of pressure will allow the entire plunger assembly to move abruptly to its right end position, as shown in Fig. 12. The full flow entry of fluid through port 160 into the bypass plunger case 130, and the full flow outlet of fluid through port 159 from the bypass plunger case are important and are especially provided to induce rapid movement of the bypass plunger, whereby the momentum thus attained will fully open said ports. When the bypass plunger assumes its original righthand position then fluid from the pump through the pipe 147 will be closed off, as shown in Figs. 5 and 12, and unobstructed passage is provided through port 100 and pipes 149, 117, 114 for the fluid to pass from the stem end of the reversing valve on into ports 101 and 103, which latter ports are always maintained at tank pressure through their connection to the main tank line 90.

The tank pressure which is normally exerted on the lefthand end of the reversing plunger B through openings 101, pipe 170 and open valve 174, and on down through pipe 114 is thus exerted upon the left end of the reversing plunger which, being of larger area than the righthand end,

which is now subjected to equal pressure, said greater lefthand area causes the plunger to move abruptly to the right into its original position, as shown in Fig. 10, at which time the power and bypass valve plungers will also be in the original position, as shown in Fig. 5, which completes a pumping cycle.

It is here explained that the hand valve 174 in pipe 170 normally remains open during automatic operation of the reversing mechanism, and is only closed as occasion might arise to temporarily discontinue existing automatic operations for the purpose of re-adjusting same as is herein more fully explained.

The construction and varying positions of my reversing valve plunger B, relative to the ports in the reversing valve housing within which the plunger reciprocates, comprises an important feature of this invention, which will now be explained. During the movement of said plunger in either direction and before completion of either of its fluid flow reversing functions said plunger reaches an intermediate lateral position within said housing in which position or at which time all the openings, ports, passageways and areas within the reversing valve housing and also in the power pump, including both inlets and outlets to and from said pump are all temporarily exposed to a common or equal fluid pressure, which pressure will be the pressure which normally exists in the storage tank and throughout the entire piping system. When the power pump is not functioning or putting up pressure which is temporarily the case when said reversing plunger B is in said intermediate position, the inlet and outlet sides of the pump are so interconnected and exposed to each other that the pump though still rotating is momentarily not functioning or creating pressure. The above results occur and is specifically and intentionally brought about in my construction to absolutely prohibit the closing of either a fluid inlet or outlet in the continuously running pump until an alternate fluid outlet or inlet is open to substitute for the one to be closed. The closure of either the inlet or outlet to or from the pump before the opening of an alternate inlet or outlet in the pump would cause a very abrupt high pressure fluid peak load tending to stop movement of the motive unit or burst the pump or its associated piping. Even at low pressures such a closure causes severe hydraulic shocks and noises in the system and piping which are commonly referred to in the hydraulic arts as "water hammer", and furthermore any such closure of the pump inlet or outlet would cause unnecessary consumption of H. P. To avoid all the above undesirable features I therefore provide that before either the inlet and outlet being used are closed another inlet or outlet is opened, consequently, as above explained, fluid pressure equalization momentarily occurs, and said pressure equalization which is transmitted to both ends of the plunger B, would instantly stop its left-hand movement if power were not derived and applied to the right hand end of said plunger from another source to continue the reversing stroke of the reverse plunger to the left. However, as elsewhere herein explained, when the reverse plunger reaches this intermediate position my power valve performs its duty, which is to supply sufficient hydraulic pressure or power to complete the left-hand stroke of the plunger B without any noticeable slowing up of its movement.

It is frequently required under varying pumping conditions to terminate the down stroke of

the ram 24 before the ring 45 on the bottom of the ram has descended to or below the fluid outlets from under the ram. In such cases the descent of the ram will be checked by the timed operation of the fluid-flow reversing valve. The initial checking of the ram's descent will occur when the reversing plunger reaches the aforesaid intermediate position at which time fluid from under the ram has an obstructed passage from pipe 91, through the reversing valve and pipe 90 to the air tank. The compressed air in the tank is thereby initially applied to check the descent of the ram and offers a flexible cushioning medium for so doing.

The fluid forced out from the power pump into pipe 91 of the fluid flow reversing valve passes to the pumping jack previously described and acts to engage below the ram therein and elevate the ram and its load of rods and liquid. In actual practice a plurality of wells may be pumped simultaneously and in Fig. 2 is illustrated an installation for this purpose. The pipe 91 is shown as extending out to conduct the pressure fluid from the pump to a plurality of jacks. Branch lines 47, 47a and 47b conduct the lifting fluid to jacks 180, 181 and 182, respectively. Hand operated valves 183 are provided in each of the branch pipes to regulate the rate of flow of the lifting fluid through the same. It will be understood that each well has its own characteristics as to depth, volume of production, and the like, and each jack may therefore differ in the length of its stroke. The valves 183 may, therefore, be adjusted for each well, to pass the required volume of lifting fluid to elevate the jack on that well to its required stroke length.

I employ in connection with the pumping system a fluid pressure storage tank having a compressible expansible fluid such as air therein, the pressure of which serves to counterbalance the weight of the ram, sucker rods and pump mechanism on the down stroke thereof, and also stores up energy and power derived from the falling loads of ram, rods, and pump plunger, to assist the motor-driven pump in elevating said elements together with the load of pumped liquid on the next upstroke.

In constructing my tank I provide an air storage chamber 184, which as shown particularly in Fig. 2 is rectangular in shape. The body of the air tank comprises a tubular member, the two side members being connected to the end members 185 and 185', by welding or other equivalent means. There is thus provided a continuous internal tubular chamber for the air which chamber is of large volume and yet is adapted to lie low upon the ground and form a base upon which the motor, power pump and its control mechanism may be mounted. This therefore provides a support for the complete pumping unit which with the tank is easily portable from place to place when the location thereof is to be changed.

This base member 184 is one closed chamber but it has connection with the liquid containing tanks which are mounted thereon, as shown in Fig. 3. At one end 185 of the base member I mount two liquid tanks 186 and 187 respectively, which are spaced apart upon the end member. They have no connection whatever with the air tank except as will be presently described.

The liquid-containing tank 186 has a direct connection through the fluid flow reversing valve with the power pump and may hence be called the liquid supply tank. It is closed at its lower end, where it is mounted upon the air tank, ex-

cept for a central opening 187 therein to allow the passage therethrough of a connecting pipe 188. Said pipe 188, which is welded or otherwise sealed off from communication with the air chamber 184, extends upwardly into the liquid supply tank to a point adjacent the upper end thereof. The upper end of the tank 186 is reduced in diameter and closed by means of a plug 189 screwed therein, said plug having a central passage 190 which is normally closed by a screw threaded plug 191.

There is a lateral pipe 192 connected with the upper end of the liquid tank which has a hand-operated valve 193 thereon which may be opened to provide connection with the pipe 131 previously mentioned as leading to the container 128, shown in Fig. 5 at the inlet to the compressor D.

The tank 187 is likewise sealed off at its base from the air chamber but a downwardly extending pipe 194, which is also sealed off from the air chamber, is open to the tank 187 at its upper end and connects to pipe 188 at its lower end. It will therefore be seen that the pipe 188 connects the two tanks 186 and 187 so that the pressure of the fluid therein is equal. Said downwardly extending pipe 194 has the effect of further extending the depth or length of the head of liquid in the tank in actual practice for an additional foot or more and this is of importance as will be hereafter explained.

The tank assembly is normally charged with air or other suitable gas and with oil or other suitable substantially non-compressible liquid in proper volume and pressure at its point of manufacture and the required volume and pressure of the fluids used is maintained and any loss due to leakage is replenished by means of the aforementioned compressor or pump D, which is designed to pump any kind of desired fluid from the container 128 through pipe 127 and discharge same through pipe 137 into the upper end of the tank 187. There is normally an air space 195 in the upper end of the tank 187. The upper end 196 of the tank 187 is reduced in diameter and has an opening which is normally closed by the hand operated valve 199. There is also a laterally extending pipe 200 leading from the upper air storage portion of the tank 187 which is connected with an upright air conductor pipe 201. I provide in pipe 200 a hand-operated valve 202 by means of which the air pressure from the chamber 184 may be cut off from the liquid tanks, and I may also connect therein a pressure gauge 203 by means of which the fluid pressure in the system may be noted.

The pipe 201 extends downwardly through the upper wall of the air storage tank 184 and may be understood as being welded in position to make a fluid tight connection where it passes therethrough. The lower end of this pipe extends to a point closely adjacent the lower end of the air storage chamber and is adapted to convey and apply the air pressure from the chamber 184 to the top of the liquid in the air oil storage tank 187 whence said pressure extends throughout the entire closed system. I provide at the upper end of the pipe 201 a relief valve 204 which acts as a safety valve to relieve excess pressure beyond a predetermined amount.

The pressure fluid storage installation thus provided has several advantageous characteristics. Tanks heretofore used for this work are relatively bulky to accommodate the volume of fluid required and are ordinarily constructed in the form of a cylinder approximately sixteen or eighteen inches

in diameter and from fifteen to twenty feet in length. Such tanks must be stood on end in order to attain a considerable head or depth of the oil which is essential in order to maintain the separate identity of the two fluids, air and oil, for instance, which in this work are stored in direct contact with each other in the tank. Therefore, previous tanks had to be erected and maintained in an upright position which requires use of foundations and guy wires or other supports to prevent their falling. Furthermore, if such tanks are to be charged or filled with the two fluids at the factory they become intermixed in transit and rendered unfit for their required function.

The operation of this installation may now be noted. Referring to Fig. 2, oil from tank 186 is pumped by the power-operated pump and discharged past the fluid flow-reversing valve and outwardly through the pipe 91 to the pumping jacks where it serves to elevate the rams therein together with their loads. The valves 183 in the branch line leading to the separate jacks will be adjusted by tests so that during the time of the fluid discharge thereto the rams in the jacks indicated diagrammatically at 205 will be raised the desired amount to operate the particular well on which it is installed. Each valve 183 may be thus adjusted so that during the working stroke of the pump each jack cylinder will receive the amount of liquid under pressure to elevate the ram therein to the desired height necessary in the particular well upon which the jack is placed. In Fig. 2 the jack 182 is indicated as requiring a shorter stroke than are the other two jacks. This may readily be accomplished by the adjustment of the valve 183 leading thereto. Thus each of the rams in each of the jacks will be elevated the proper amount required for the particular well upon which the jack is placed.

When sufficient liquid under pressure from the power pump has been delivered to elevate the jacks as required the fluid flow reversing valve will be reversed in the manner which has been described so that the liquid can pass back from under the rams in the jack through pipe 91, thence through the reversing valve down into the pump which applies sufficient additional power to force said liquid outwardly through pipe 90 on into the liquid storage tank 186. It must be understood that the fluid in said tanks is always maintained at such pressure that during the up-stroke of the jacks the pressure in the tank bears substantially the same relation to the pressure required to elevate the rams as the pressure created under the rams by their gravitational down stroke bears to the pressure in the tank. This equalization of pressures during the entire up and down pumping strokes results in a substantially uniform and continuous power demand from the motive unit. There is no variation between the up-stroke and down-stroke power demand upon the motor except that created by the insignificant slight drop and raise in the tank pressure as liquid is taken from and forced back into said tank. Thus, when the rams in the separate jacks are falling under their separate loads, the pressure exerted thereby upon the liquid under the rams will be applied to aid the power plant in forcing said liquid back into the tanks, thus further compressing the compressed air stored therein and storing up the gravitational power thus conserved as well as at the same time storing up in the form of compressed air the power of the continuously running motor which otherwise would be idle during the down-stroke of the rams.

When the reversing valve is again shifted to discharge the fluid through the pipe 91 to again elevate the jacks the H. P. of the motor will be aided by the flow of liquid from the tanks into the intake side of the pump through the pipe 90, and this is so because the power stored up in the tanks in the form of compressed fluid will exert its expansive force against the oil which it contacts at the top of the tank 187 and force the liquid out of the tank 186 into the power pump and thus aid the motor in performing its up-stroke.

During the normal operation of the system air and/or liquid will be discharged from the small pump or compressor through the pipe 137 into the upper end of the tank 187. I have found that when air under pressure, as is required in this system, is in contact with and about the oil, as shown in tank 187, said pressure causes the air to pass or be absorbed into the oil and I have found further that increasing the depth of the oil lessens this mixing of the two fluids. By arranging the air tank 184 as shown and mounting the liquid tanks thereon and further by downwardly extending the pipe 194 below the tank 187 I attain in a low compact type of tank a maximum depth or head of oil into which less air will enter. The amount of air which enters the oil increases substantially relative to any increase in pressure, or to any decrease in depth or head of the oil.

Air entering the oil will pass down through the oil in the tank 187 and pipe 194 thence across and up through pipe 188 to the upper end of the tank 186, where it will accumulate and whence it can, either steadily or at intervals, through valve 193, be drawn off before it mixes with the oil in the lower portion of tank 187 from which the oil supply to the power pumps is drawn. When said undesired air is drawn off the top of tank 186 a small amount of more or less foamy or air-impregnated oil may also pass with the undesired air and such oil if any passes into and through pipe 131 to the container 128 which is connected with the compressor D in the manner described. I am thus enabled to substantially prevent the leakage of air through the oil to the outlet pipe 90, which leads to the power pump. This, as may be well understood, prevents access of air to said pump in such quantity as to decrease the efficient operation thereof and further by my deep oil sealing means in tank 187 which minimizes entry of air into the oil, pressure drop in the tank is insignificant even over a long period of time.

I employ oil as the actuating medium between the power pump and the jack because of its superior lubricating qualities and its non-oxidizing characteristics. I find, however, that water resists the passage of air therethrough under pressure to a much greater extent than does the oil. In Fig. 4 I have illustrated an installation whereby I may provide a volume of water between the air pressure chamber and the oil discharge system which leads to the power pump and the jack. The tank 187 and its connection with the pipe 201 is in this case identical with the previous installation. I provide however between the tank 186 and the connecting pipe 188a a separate liquid containing tank 206. The U-shaped pipe 188a connects between the lower part of this third tank 206 and the original tank 187 which is provided with the same equipment as was disclosed in Fig. 3. The pipe 188a in this modification however does not extend to the upper end of either

tank and is shown as extending to a point slightly above the bottoms of the tanks 206—187. The upper end of this third tank 206 is closed by a small screw plug 208. A pipe 209 connects the upper end of the two tanks 206 and 186. Said tank 186 is provided with equipment as is disclosed in Fig. 4.

With the installation thus constructed I fill tank 186 and a large proportion of the tank 206 with oil. The tank 187, however, is filled with water, said water filling also the pipe 188a and the lower part of the tank 206 up to a level indicated at 210. It will thus be seen that the oil and water will be separated by gravity so that the oil will lie above the water in the tank 206. However, the air pressure entering tank 187 through the pipe 201 will be exerted against a water medium. Thus if bubbles of air tend to pass through the liquid toward the discharge pipe 90 leading to the power pump it will have to first pass through the water in tank 187 and the pipe 188a and also through the water in the lower part of the tank 206 before it may reach the oil in the remaining portion of the system. This installation is somewhat heavier and expensive but where high counterbalancing pressures are required in the air chamber as is necessary in pumping from wells of extreme depths I find that such high pressures when applied directly to the oil as is shown in tank 187, Fig. 3, cause such a mixture of the fluids as to lower the mechanical efficiency of the power pump, therefore the introduction of my water sealing means between the air and the oil provides a more economical and efficient method of pumping deep wells.

Referring to Fig. 4, it will be seen that near the top of the third tank 206 I have provided a pipe 192', a valve 193', and a pipe 131' through which air may be drawn off in the same manner as through pipe 192, valve 193, and pipe 131, in the top of tank 186. Also in Fig. 4, near the top of tank 186, I have provided a pipe 137' through which fluid may be supplied to said tank from the compressor D or any other source.

I have previously described my air compressor D as operated in connection with the power valve. This positioning and operation of the compressor has the advantage of placing the compressor where the barrel may be cooled by liquid within the body of the power valve case 104. In this way the compressor may be kept from overheating without difficulty.

I may, however, place an air compressor in position adjacent the pipes running to and from the reversing valve so that the said compressor may be operated by fluid connections with these two pipes. This is illustrated in Fig. 2. With reference also to Fig. 6, the construction of this compressor may be seen. The power cylinder 215 is shown as connected at one end 216 to a fitting 217 which closes that end of the cylinder except for the lateral pipe 218. Said pipe is connected through the pipe 219 with the pipe 91 as shown in Fig. 2. The opposite end of the cylinder 215 is provided with an integral head 220 within which a smaller cylinder or barrel 221 is provided to serve as the compressor or pump cylinder. Connected with the compressor end of the cylinder 215 is a pipe 222 which makes connection with the pipe 90, as will be seen in Fig. 2. Within the cylinder 215 is the plunger 223 which fits slidably within the cylinder and is adapted to be reciprocated by pressure fluid entering through the ports 219 and 222. Upon the plunger 223 is a longitudinally extending stem 224 which has a head 225

thereon adapted to engage at one end of the stroke of the piston within a recess 226 in the head 217. The entry of said head 225 into said recess 226 provides a gradual hydraulic stop or termination of the travel of plunger 223 at its extreme righthand position.

On the opposite end of the plunger 223 is an axially extending plunger 227 of smaller diameter adapted to fit within the cylinder or barrel 221 and act to pump air or liquid to the pressure fluid tanks.

There is an outlet pipe 228 from the end of the cylinder 221 leading to the pipe 137 at the upper end of the fluid tank 187. Connected with the outlet port 229 from the cylinder 221 is the valve housing and valve retaining means which is identical with that disclosed in Fig. 5. At the intake side 230 of the cylinder 221 is a fitting and valve connected therewith also the same as those shown in Fig. 5 in connection with the compressor there disclosed.

The operation of this compressor will be readily understood. When the liquid pumped from the power pump flows outwardly through pipe 91 to the pump jacks there will be liquid pressure exerted through the pipe 219 into the power cylinder 215 of the compressor. The areas of the opposite ends of the piston 223 are so proportioned that pressure exerted by this liquid against the righthand end of the piston will be sufficient to move the compressor piston 227 in the cylinder 221 to the left to compress any fluid which has entered said cylinder through the inlet 230 and force said fluid outwardly through the pipe 228 to the fluid pressure tank 187. When the direction of flow of liquid from the power pump is reversed and the jacks are moving downwardly the pressure of the fluid through the inlet pipe 219 will be decreased below the pressure in the pipes 90 and 222 to such an extent as to cause the power piston 223 to again move to its righthand position, during which righthand movement fluid enters the compressor cylinder 221 through the inlet pipe 230 whereupon the mechanism is ready for the next stroke.

It will be obvious that the suction stroke of the compressor will require but small consumption of power to move the piston and the amount necessary for this purpose is supplied through the pipes 90, 222. The movement of the power piston 223 on its suction stroke will bring the head 225 on the stem 224 within the recess in the cylinder head 217, and thus limit the movement of the piston in that direction. It will be understood that this form of compressor may be substituted for that shown in Fig. 11 whenever desired and particularly when the type of power valve shown in that figure is not employed. The use of one or the other forms of the compressor member will be optional and the use of one or the other will depend upon the other elements of structure employed therewith.

I have shown in Fig. 5 a power valve and bypass valve which may be employed in controlling the movement of the plunger in the fluid flow reversing valve. It will be understood that the particular structure shown in Fig. 5 may be modified in many ways without departing from the inventive idea therein disclosed. In Fig. 20 a substitute structure is illustrated. Instead of the power valve and bypass valve being separately formed and mounted I combine the two in one connected structure.

In this embodiment of the power and bypass valve I provide a base member 231 which is

adapted to seat upon the upper end of the fluid-flow reversing valve and have connection at 232, 233, 234 and 235 with ports 100, 101, 102 and 103, respectively, in the reversing valve housing. The base member 231 may be understood as forming a support upon the reversing valve housing and also to form passages therethrough for fluid passing to or from the ports in said fluid flow reversing valve housing.

The upper end of the base member 231 has connection with the cylinder 236 of the combination power and bypass valve. Said cylinder has a head 237 at the lefthand end, as shown in Fig. 20, said head having an opening therein to receive a threaded plug 238 by means of which said opening is normally closed. At the opposite end of the cylinder 236 is a head 239 which is screwed within the end of the housing and closes that end except for an opening 240 therein to allow the reciprocation through said head of a hollow stem 241. In the outer end of the opening in said head is a tubular cap member 242, the inner end of which forms a gland to compress packing 243 around the stem 241. The outer end of the cap member is provided with a closure plug 244 having an opening 245 therein through which air may pass in the operation of the valve. The stem 241 is hollowed out toward its outer end for purposes of lightness and its inner end is provided with a radial flange 246 which bears against the inner surface of the head 239 to limit the outward travel of the stem.

Within the cylinder 236 is a plunger member 247. Said plunger is in the form of a hollow plunger, the left-hand end of which is open for purposes of lightness while the righthand end thereof is closed, as shown at 248. The closed end of the plunger has a longitudinally extending collar 249 thereon which furnishes connection with an intermediate stem 250 which is connected at its other end with the stem 241. In this manner the plunger and the stem 241 are rigidly connected to the intermediate stem 250 so that all three parts are moved together as one member.

Between the flange 246 of the stem 241 and the plunger 248 I provide a floating valve member 251. This member fits closely within the cylinder and has a central opening 252 therein which is spaced outwardly from the intermediate stem 250 but is of smaller diameter than is the flange 246 on the stem 241. Thus when the plunger 248 is moved to the left of its position shown in Fig. 20 the flange 246 upon the stem 241 will engage against the floating valve 251 and move the same toward the left. It will be seen, however, that when the plunger is moved in the opposite direction the end of the plunger 248 will cause the movement of the floating valve member 251 in the opposite direction.

In the body of the cylinder and base member which has been described I form a U-shaped passage 253. This passage is connected through one arm 254 thereof with the interior of the cylinder 236 at a point spaced somewhat from the head 239. The other arm 255 of said U-shaped passage extends through the wall of the cylinder at a point spaced a predetermined distance relative to the position and travel of the plunger 247.

Between the port 232 in the base member and the U-shaped passage just described I provide fluid connection through the pipe 256 as shown in dotted lines. In this pipe I place a hand-operated valve 257 for control of the fluid passing therethrough.

The port 234 in the base member is connected

by a pipe 258 with the cylinder 236 at 259, the port being formed through the wall of the cylinder 236 at a point intermediate the ends thereof so as to supply fluid to said cylinder at a predetermined time, as will be later noted. There is in the pipe 258 a check valve 260 allowing the passage of liquid therethrough in the direction of the arrow shown in dotted lines adjacent said valve.

I also provide connection between the pipe 258 and a pipe 261, which extends parallel with the longitudinal axis of the cylinder 236. The outer end of said pipe 261 is closed by a plug 262 and adjacent this closed end a branch pipe 263 is connected. Spaced from the end of the pipe 261 is a second branch pipe 264. Both branches 263 and 264 are joined with a pipe 265 which in turn is connected through the side wall of the cylinder 236. In the pipe 263 is a check valve 266 and a hand-operated valve 267. The check valve 266 allows the passage of liquid therethrough toward the cylinder. In the pipe 264 is a check valve 268 which allows the passage of fluid away from the cylinder and into the pipe 261. The hand-operated valves 267, 269 are employed to restrict the flow of fluid therethrough to the amount desired.

There is also a branch pipe 270 connected with the pipe 261 and extending through the wall of the cylinder 236, at 271. In this pipe 270 is a check valve 272 through which fluid may flow from the cylinder to the pipe 261.

The operation of the device shown in Fig. 20 performs all of the functions of the separate power valve and by-pass valve disclosed in the Fig. 5 embodiment except that the air compressor D is not shown in Fig. 20, but same could be installed in place of the plug 238, if desired. Before the pump is started the power valve plunger assembly assumes the position shown in Fig. 26 as the fluid pressure from the tanks is always applied to the larger or left end of said plunger, which, except when high pressure pumped fluid is applied to the right end of said plunger moves and maintains said plunger towards the right end of the cylinder 236.

Tank pressure passes from pipe 90 through the port 101 of Fig. 5, which port interfits with passage 233 of Fig. 20, whence said tank pressure is led through 233' to the left end of the power plunger 247. When the pump is started the high pressure pumped fluid from pipe 91 passes through port 102 of Fig. 5, which interfits with port 234 of Fig. 20, and thence into pipe 258, and will pass through the pipes 261, 263, and 265 into the righthand end of the valve cylinder. The passage of fluid through the pipe 263 will be restricted or choked through the setting of the valve 267 so that the movement of the valve plunger 247 may be properly timed as desired. Fluid entering through the pipe 265 into the cylinder 236 will engage against the valve plunger 247 and move the same gradually toward the left against the pressure of the tank fluid always existing at the opposite end of the cylinder.

As the plunger is moved the floating valve 251 will remain stationary until a flange 246 on the stem engages therewith after which the valve 251 will also be moved toward the left. This movement will be slow until the closed end of the plunger has passed the opening 259. When the righthand end of the power valve plunger 247 has moved to the left sufficiently to open the port 259 in the cylinder wall fluid under pressure from the power pump will enter in full volume behind the

plunger and move it abruptly toward the cylinder head 237. With the valve in this position fluid under pressure from the pump may pass from the power pump through the opening 234 and pipe 258 into the power cylinder to eventually pass downwards out of the cylinder through passage 254 and the pipe 256 and on into the righthand end of the reverse valve and said pressure will be sufficient to start movement of and force the plunger B part way to the left. Completion of the lefthand movement of the reverse valve plunger B will be performed in this instance by the action of this power plunger 247 in the same manner as has been previously described in explaining the operation of the power plunger 105 in the first described power valve C.

With the power applying function of the fluid-flow reversing valve fully completed the direction of the flow of fluid will be reversed and further return of the plunger 247 towards its original righthand position may then be permitted as fast or slowly as desired, the liquid within the righthand end of the power valve cylinder being hand regulated to exit through the pipe 265, the valve 269, the pipes 264, 261, and 258 to the port 234 which is now the low pressure side of the pump.

When the power plunger has forced the reversing plunger B to the left, further righthand movement of the power plunger will be slow due to the restricted outflow of fluid from the cylinder until the floating valve member 251 has passed the opening 271 whereby liquid may escape to the annular opening 273 and the port 271 in full volume, thus allowing the plunger to move abruptly to the righthand end of its stroke, thus completing the cycle of operations. The plug 275, shown with its inner end extending through the wall of the power cylinder, acts as a stop to prevent the floating piston from passing too far towards the right due to momentative forces.

It will be seen that this structure accomplishes the same results, with the exception of the operation of the compressor, as is accomplished through the structure of the power valve and by-pass valve disclosed in Fig. 5. It is obvious that other and different jack stroke control and reversing apparatus may be employed without departing materially from the scope of the invention.

What is claimed is:

1. In combination, a hydraulically operated pump jack, a power pump to supply pressure fluid to said jack, a fluid conduit from said pump to said jack, a fluid flow differential reversing valve in said conduit operable to direct flow to and from the pump and jack, and timing means connected with said valve and operable by the pressure of fluid flowing through said valve to successively apply equal and differential pressures to the valve to move said valve first in one direction and then in the other to direct the flow of fluid from said pump to said jack and back therefrom.

2. A pump jack, a fluid pressure storage tank, a power pump having inlet and outlet ports, a fluid flow reversing valve connected with said ports and arranged to direct fluid from said outlet port alternately through one conduit to said jack and then through another conduit to said tank, and back through the inlet port to said pump again, said reversing valve including a housing, a plunger slidable therein, passages there-through, a stem at one end of said plunger projecting through the end of said housing, means to expose the ends of said plunger to tank pressure,

and intermittent means responsive to fluid pressure from said pump to cut off pressure from the tank and to deliver pump pressure fluid to the end of said plunger adjacent said stem.

3. In a hydraulically operated pumping system, a pump jack, a fluid storage reservoir, a power pump, conduits from said pump to said jack and said reservoir, a fluid flow reversing valve controlling the flow of liquid to and from said pump, said jack and said reservoir, a timing device including a cylinder, a plunger valve reciprocable therein, a stem on said valve, projecting through one end of said cylinder to the atmosphere, fluid connections between said reservoir conduit and the end of said cylinder remote from said stem, means to admit fluid from the pressure side of said pump to the stem end of said cylinder at a predetermined rate, a port in said cylinder uncovered by said plunger at a desired interval to admit full pump pressure behind said plunger, said plunger then opening a passage for fluid under pressure to said reversing valve to move the same to reverse the direction of flow in said conduits, and means including said timing device to return said reversing valve to its original position after a predetermined interval.

4. In a hydraulically operated pumping system, a pump jack, a power pump, a fluid storage reservoir, a timing device, conduits from said power pump to said jack and said reservoir, a fluid flow reversing valve in said conduits including a housing, a reversing valve plunger movable longitudinally in said housing, a stem at one end of said plunger projecting through the end of said housing to the atmosphere, ports in said housing at the ends thereof to admit pressure fluid from said reservoir to both ends of said plunger, the port at the end of said housing adjacent said stem being connected to receive higher pressure fluid through said timing device, and a by-pass valve in said timing device controlling the higher pressure flow to said pressure inlet port at predetermined intervals to move said plunger against said reservoir pressure, said timing device acting, after a second predetermined interval, to reestablish said tank pressure at both ends of said plunger.

5. In a well pumping system, a hydraulic lifting jack, a power pump to supply pressure liquid thereto, a conduit from said pump to said jack, a pressure fluid storage tank, a conduit from said pump to said tank, a reversing valve in said conduit adjacent said pump, including a valve plunger therein, one end of said valve plunger having a smaller area than the other exposed to fluid pressure, both ends of said valve plunger being subjected to tank pressure, except when the smaller area is subjected to higher pressure, and means operating at predetermined intervals to subject said end of smaller area to pressure to move said valve plunger and again to cut off said higher pressure, said valve being then moved by tank pressure.

6. In a well pumping system, a hydraulic lifting jack, a power pump to supply pressure liquid thereto, a conduit from said pump to said jack, a pressure fluid storage tank, a conduit from said pump to said tank, a reversing valve in said conduit adjacent said pump including a valve plunger therein, one end of said valve plunger having a smaller area exposed to fluid pressure, both ends of said valve plunger being subjected to tank pressure while said plunger is in one position, and means operating in response to fluid pressure in said conduits, to subject said end of smaller area to pressure higher than the tank pressure to move

said valve plunger to its other position, and again to cut off said higher pressure, said valve being then moved by tank pressure.

7. In a well pumping system the combination of a lifting jack including a cylinder, a ram therein for reciprocation of a load, a fluid storage tank, pressure fluid therein, a power pump, fluid conduits between said pump, said jack and said tank, a fluid flow reversing valve connected in said conduits, means operating in response to the pressure of fluid from the pump to move said reversing valve at predetermined intervals, and additional means operable by the pressure in said tank to supplement the effort exerted by said first mentioned means whereby the reversing valve moves to terminal position. 15

8. In a well pumping system for control of hydraulic pump jacks, a hydraulically operable reversing valve connected to said jacks to control the inlet and outlet of the actuating liquid so as to regulate the up and down strokes of the pump jack, a hydraulically operable pilot valve connected to said reversing valve to control a flow of liquid to actuate said reversing valve, a hydraulically operable power plunger supplying supplemental liquid to be controlled by said pilot valve to actuate said reversing valve, and valve means operable to in turn control the flow of liquid from a source to actuate said pilot valve.

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