

Sept. 27, 1932.

W. E. HUBBARD

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HYDRAULIC PUMPING SYSTEM

Filed July 30, 1929

12 Sheets-Sheet 2

Fig. 16.

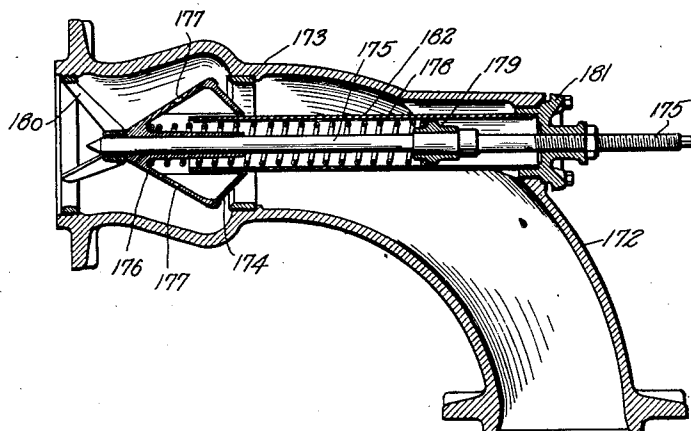
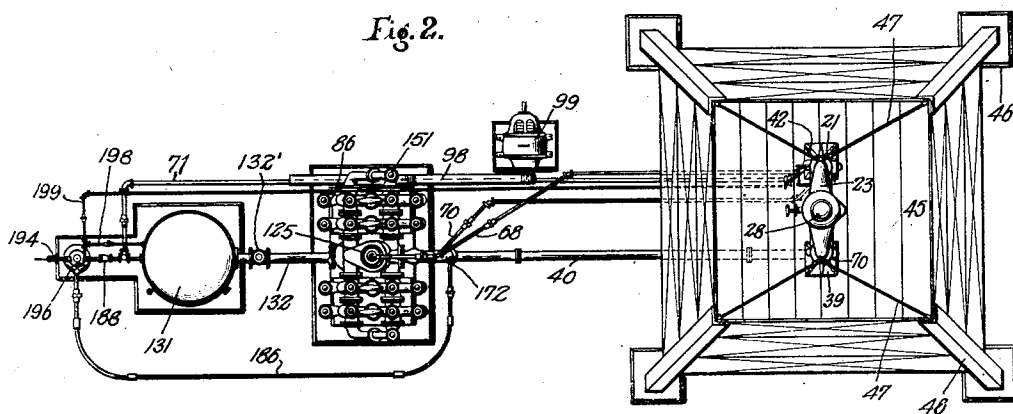


Fig. 2.



Inventor

Wm. E. Hubbard

Sol

Jack A. Schley

Attorney

Sept. 27, 1932.

W. E. HUBBARD

1,879,262

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Fig. 3.

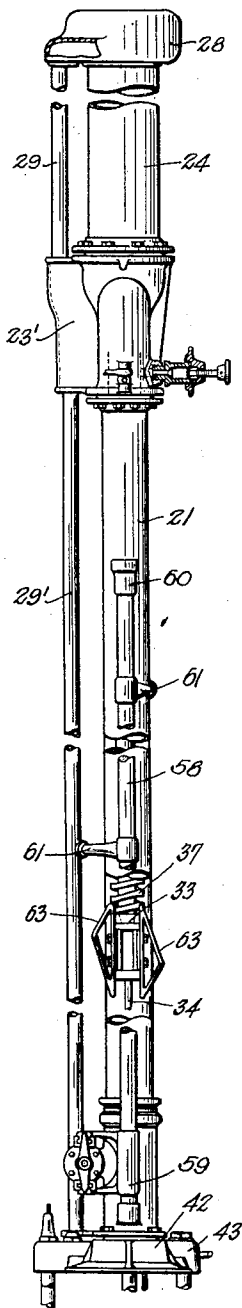
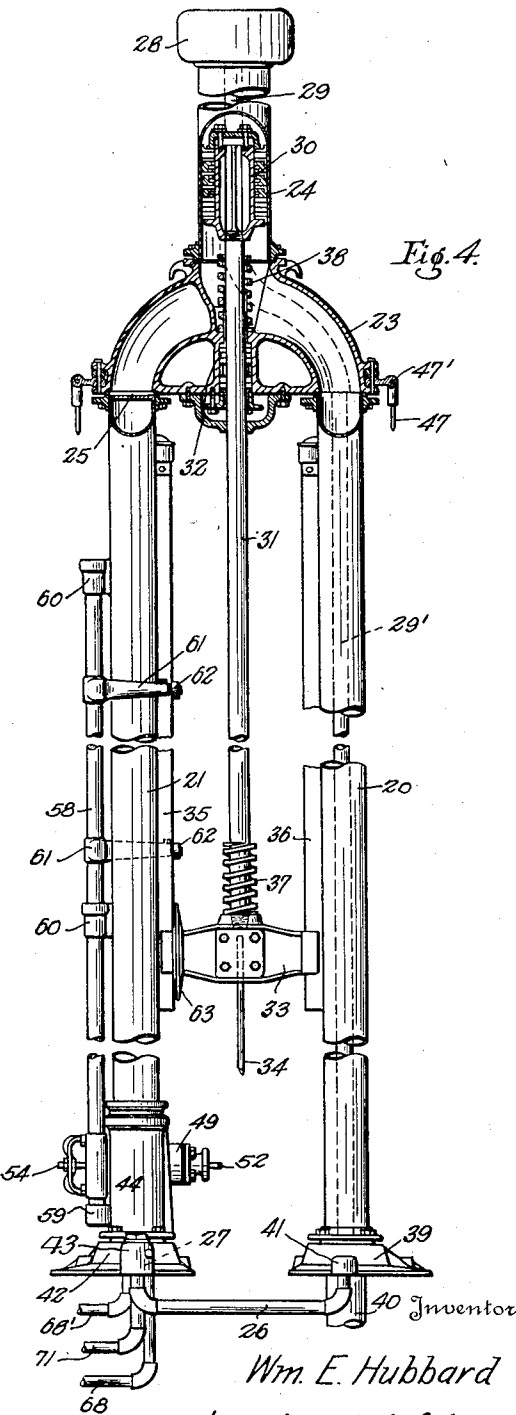


Fig. 4.



Wm. E. Hubbard

Jack A. Skelly

Attorney

Sept. 27, 1932.

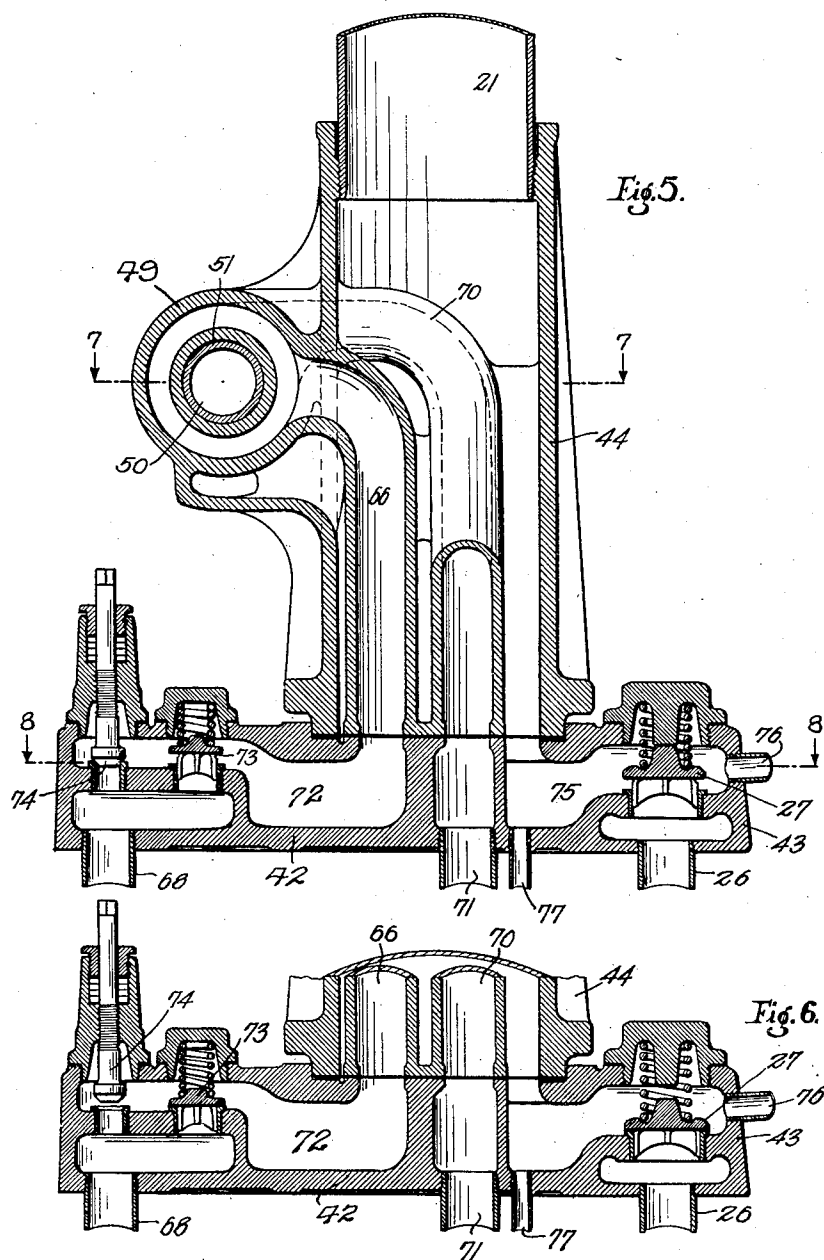
.W. E. HUBBARD

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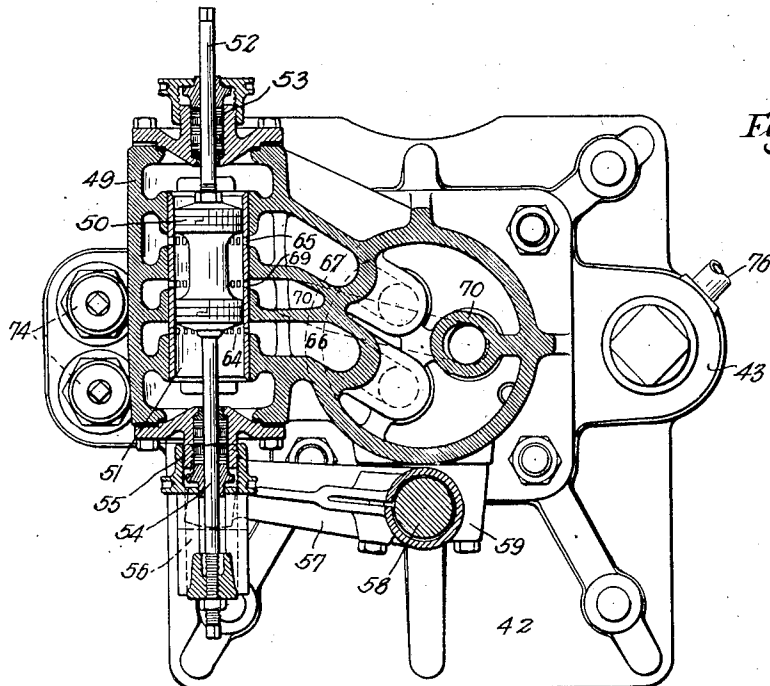


Fig. 7.

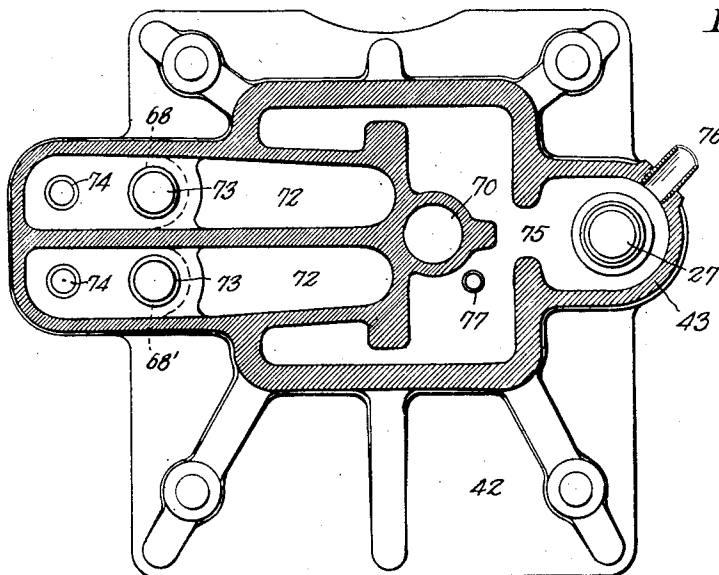


Fig. 8.

Inventor

Wm. E. Hubbard.

334

Jack A. Schley

Attorney

Sept. 27, 1932.

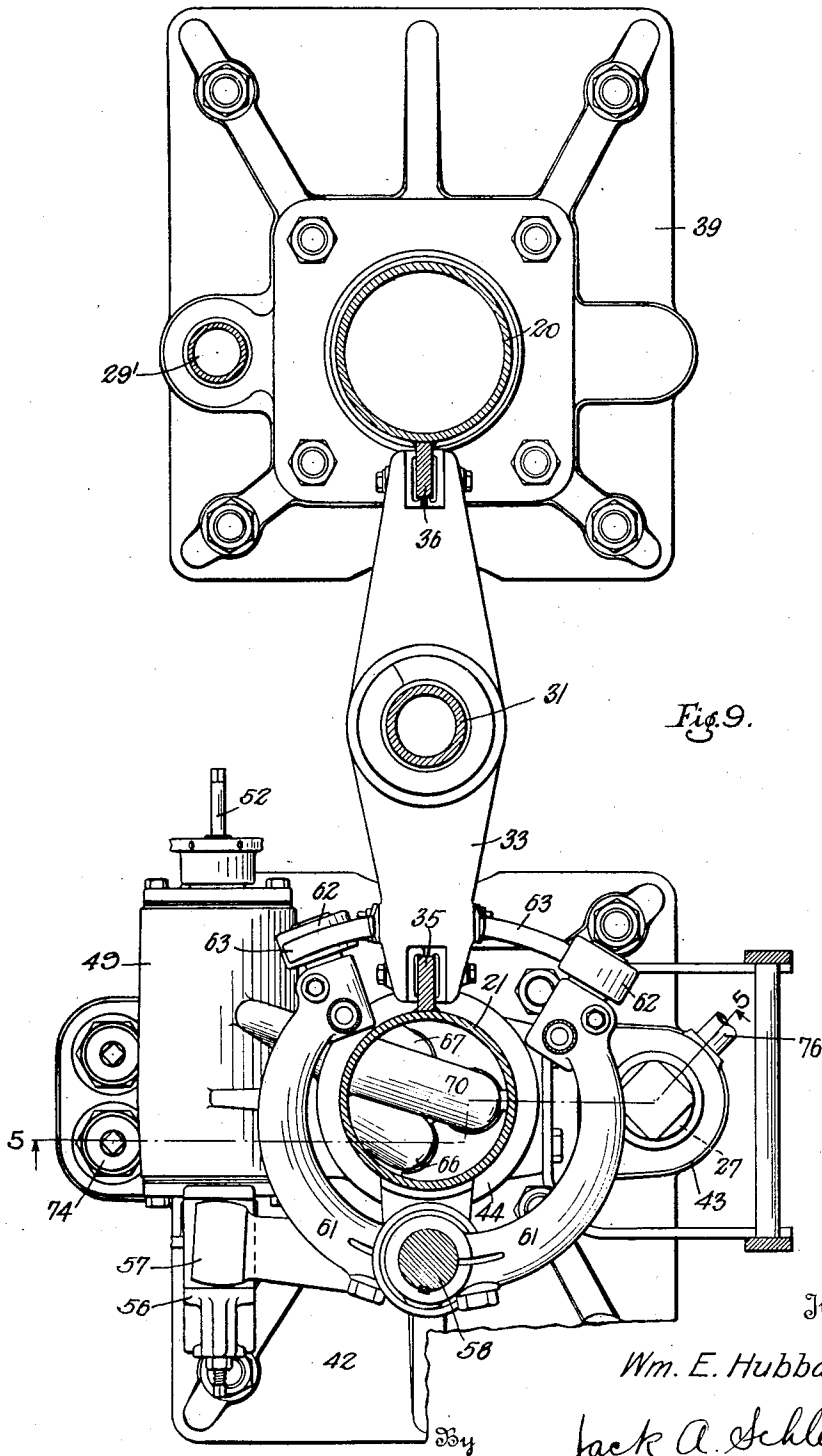
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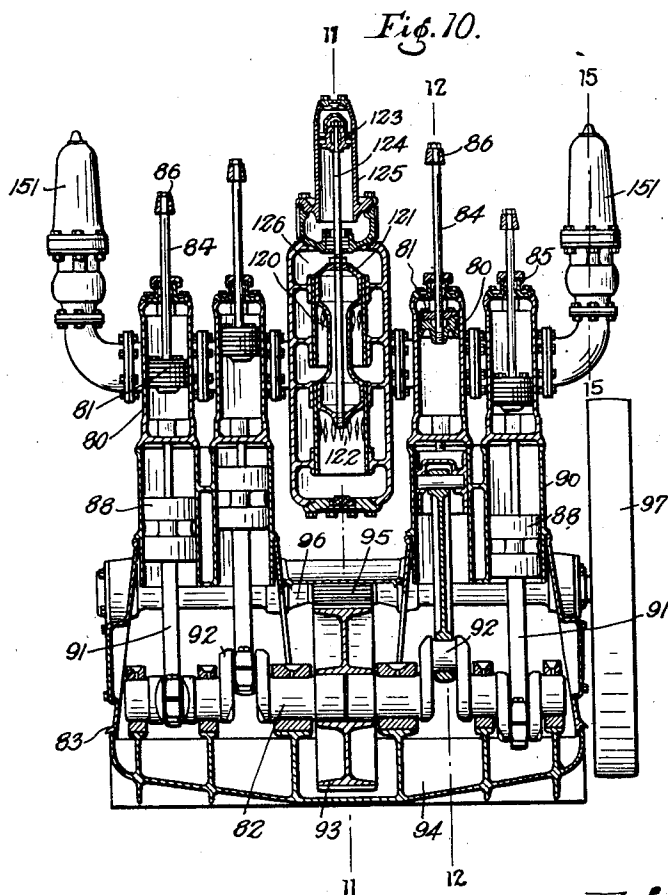


Fig. 14.

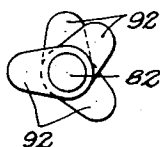
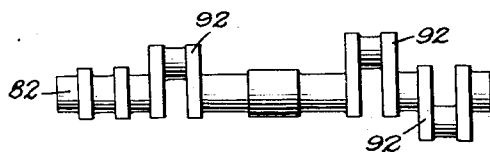


Fig. 13.



Inventor

Wm. E. Hubbard.

334

Jack A. Schley

Attorney

Sept. 27, 1932.

W. E. HUBBARD

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Fig. 11.

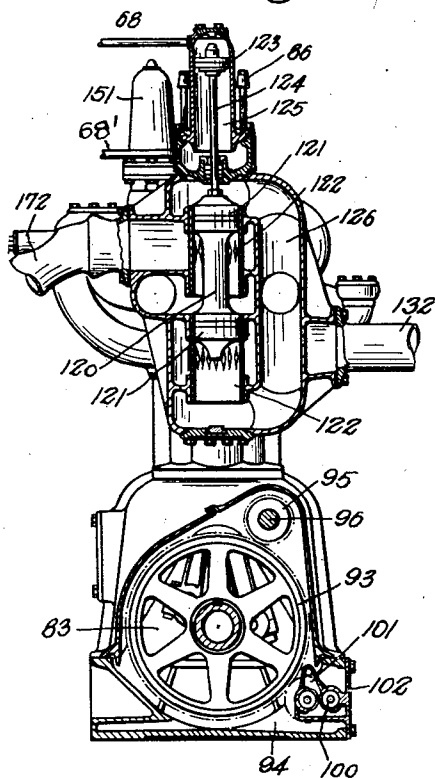
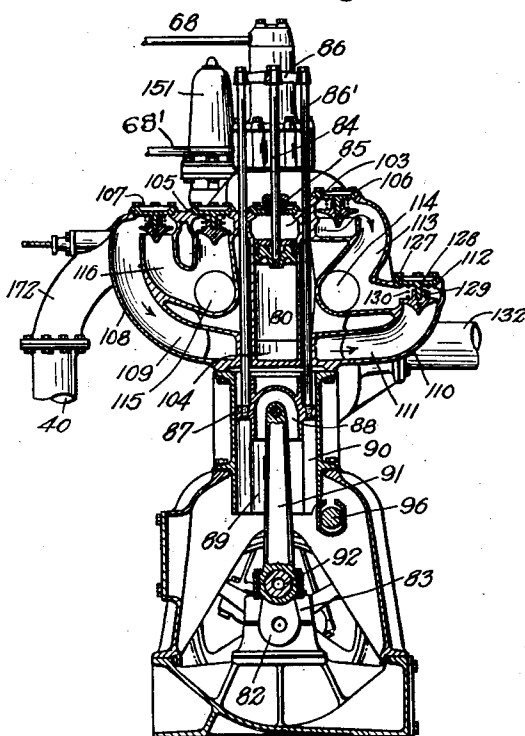


Fig. 12.



Inventor

Wm. E. Hubbard.

334

Jack A. Schley

Attorney

Sept. 27, 1932.

W. E. HUBBARD

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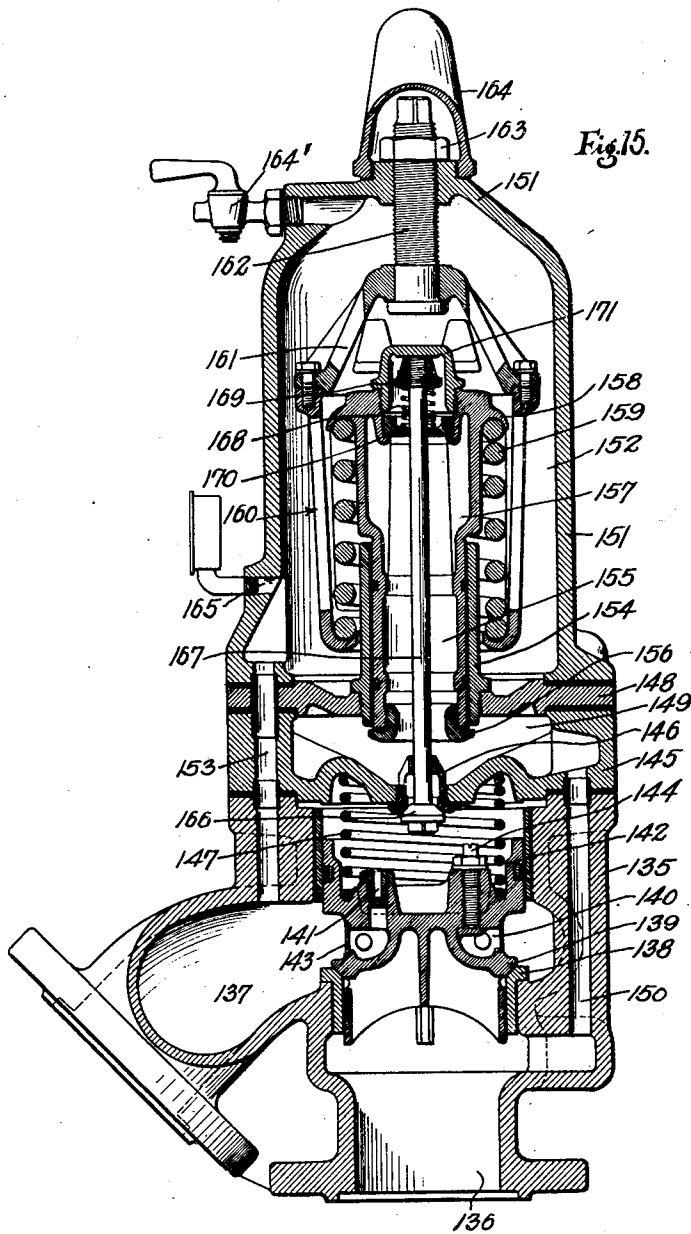


Fig. 15.

Inventor

Wm. E. Hubbard.

By

Jack A. Schley
Attorney

Sept. 27, 1932.

W. E. HUBBARD

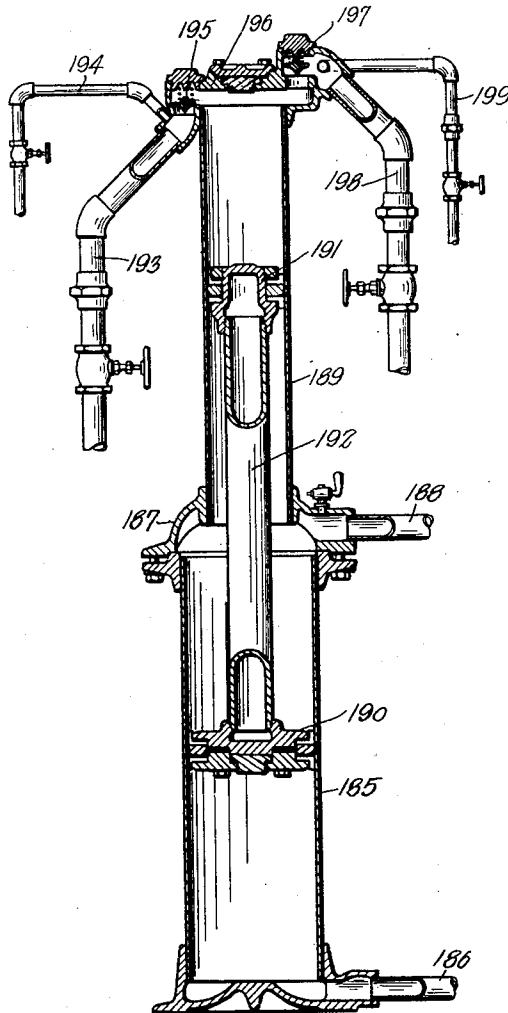
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Fig. 17.



Inventor

Wm. E. Hubbard.

By

Jack A. Schley

Attorney

Sept. 27, 1932.

W. E. HUBBARD

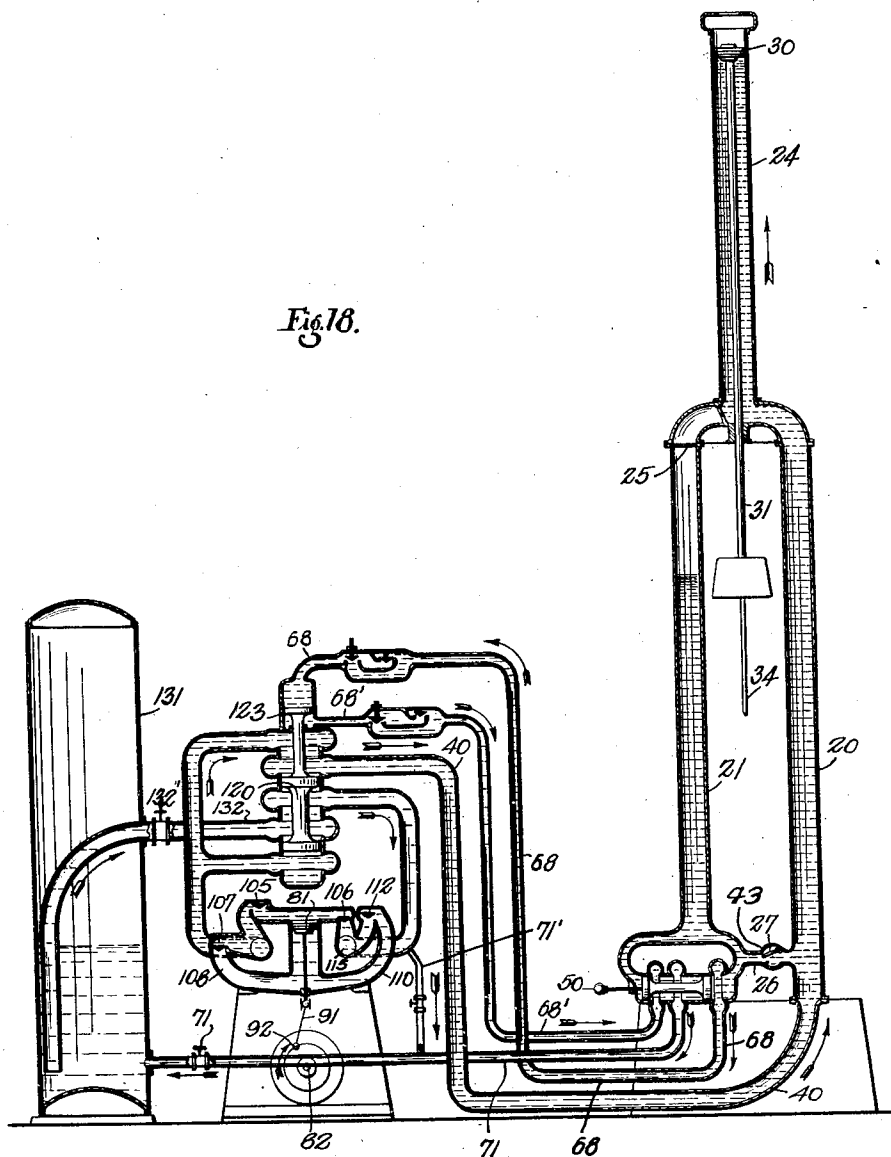
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HYDRAULIC PUMPING SYSTEM

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Fig. 18.



Inventor

Wm. E. Hubbard

By

Jack A. Schley

Attorney

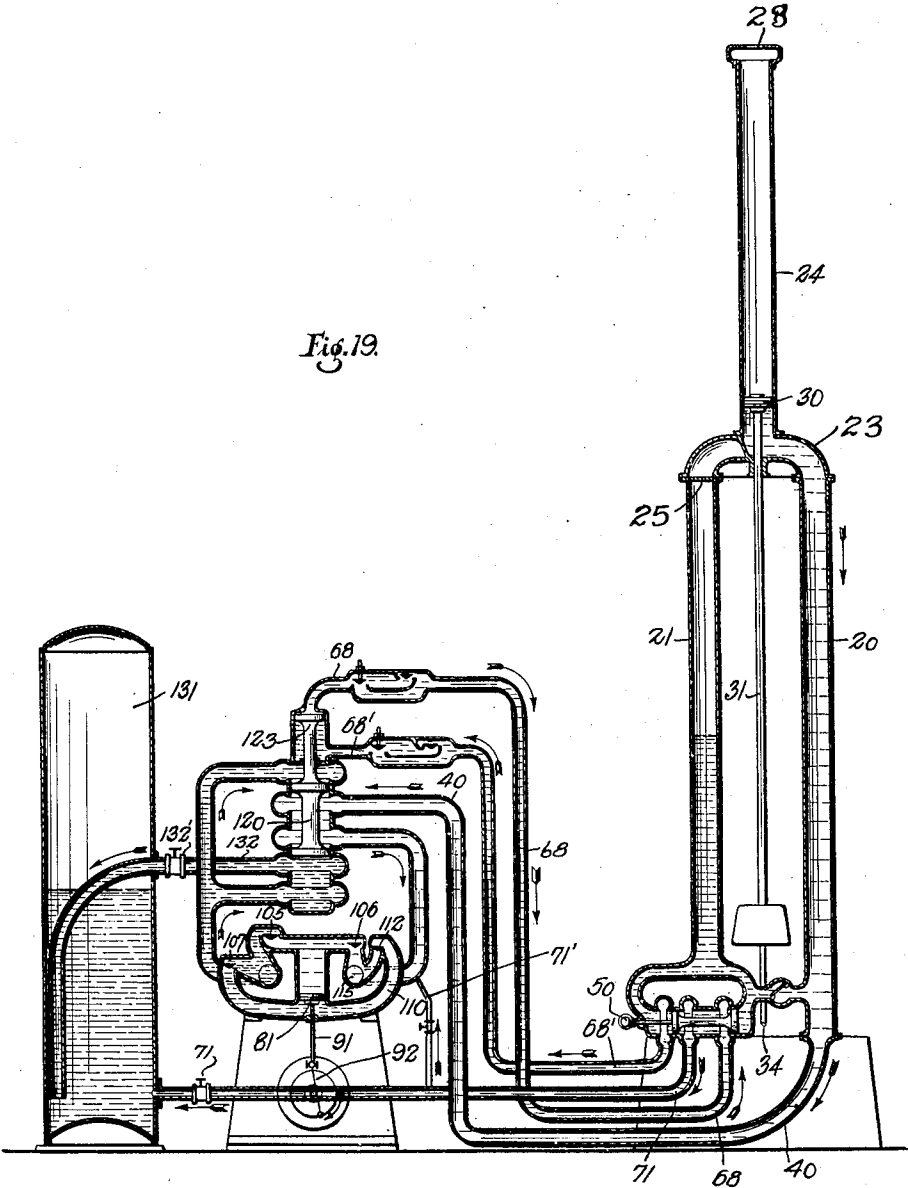
Sept. 27, 1932.

W. E. HUBBARD
HYDRAULIC PUMPING SYSTEM

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Fig. 19.



Inventor

Wm. E. Hubbard.

By

Jack A. Schley

Attorney

UNITED STATES PATENT OFFICE

WILLIAM E. HUBBARD, OF LOS ANGELES, CALIFORNIA, ASSIGNOR TO THE GUIBERSON CORPORATION, OF DALLAS, TEXAS, A CORPORATION OF DELAWARE

HYDRAULIC PUMPING SYSTEM

Application filed July 30, 1929. Serial No. 382,138.

This invention relates to a hydraulic pumping system, and more particularly to a reciprocating pump for deep wells, such as shown in my Patents 1,465,671 dated August 21, 1923; 1,619,474 and 1,619,475 dated March 1, 1927 upon which the present invention is an improvement.

In the development of such a system it has been found important to compensate for the variations of piston travel which are transmitted to the reciprocated pumping member, and to counterbalance a portion of the weight of the operating parts carried by the working head so as to secure a substantially equal stress upon the pump and its motor during both the up and down strokes of the power plunger directly connected to the well pump. In all crank driven pumps the speed of the piston varies throughout each stroke, coming to a full stop at both ends of the stroke and reaching a maximum velocity intermediate thereof. Since the load on the piston is proportioned to its speed, it follows that with uneven loads the speed is not constant. The well pump must move the liquid through a long line of tubing, the frictional resistance of which varies approximately as to the square of the velocity, so that varying velocities result.

In this class of pumping the load plunger is connected with the plunger of a working barrel pump at the lower end of the tubing, such as shown in my copending application filed July 31, 1929, Serial No. 382,405. The head of the barrel plunger is provided with a traveling valve disposed to lift the liquid load on an upstroke of the plunger and to permit the passage thereof through the liquid in the barrel during a downstroke. The barrel is provided with a cooperating standing valve at its intake disposed to open on the upstroke of the plunger to fill the barrel, but to close upon the downstroke of the plunger to support the liquid load extending to the surface level. This being the usual operation of a working barrel pump it is not more specifically described, but is referred to for explanation of the conditions which arise from the presence of gas in deep oil wells.

In such case the fluid to be raised is no longer a simple liquid, but a gaseous mixture in which any free gas is compressible and affects the operations of the traveling and standing valves. This presence of gas comprises the greatest obstacle to the constant speed of a crank driven power head as a prime mover for the working barrel plunger. In a well which has not been in operation for some time the liquid is at the level of surrounding strata, determined by either the weight of the liquid itself or by the gas pressure in the dome or source. The gas being lighter than the liquid, rises to its surface and escapes at the surface of the well, so that only liquid enters the well pump. The work of the barrel plunger at this time consists of the liquid weight and its friction against the well of the tubing, and in the initial movement of the liquid to the surface an acceleration load is developed on the power pump which is much greater than the load subsequently developed in constant operation, but the volumetric efficiency is also higher because more liquid is raised with less pump strokes.

As the pumping conditions continue the liquid level in the well is lowered and gases liberated due to reduction of pressure enter the pump barrel with the liquid during the up-stroke of its plunger. Upon the down-stroke of the plunger the traveling valve should open and transfer the liquid load to the standing valve, but if there is a body of gas beneath the traveling valve it becomes compressed and does not develop a pressure greater than the liquid above the valve so that it cannot open, unless balanced as disclosed in my beforementioned application.

In the usual traveling valve it requires more pressure on its under face to open than the pressure upon its upper face, because the exposed area of the under face is less than the exposed area of the upper face of the valve. The pressure per square inch on the lower face must be great enough to overcome the difference in area of the faces before the valve will open. Further the gaseous mixture in the barrel between the valves is compressible and owing to the large clearance necessary for practical pumping and the absence of

any substantial force to move the plunger downward, the added pressure needed to open the traveling valve is not obtainable.

The space in the barrel is sufficient to permit considerable downward travel of the plunger without raising the pressure to a point which will open the traveling valve, and in this movement the plunger has been relieved of the friction and acceleration loads of its upstroke but still carries the liquid load which causes a rapid downward movement only restrained by the dead center position of the working head.

The plunger is slowed down as the compression in the barrel increases, but the crank speed of the rotating parts is increasing as the head passes dead center which causes a conflict of the forces between the working head and barrel plunger, resulting in buckling of the rods and wear of the tubing. This non-opening valve period cannot be regulated so that it is impossible to compensate therefor by counter balancing.

When further downward travel of the plunger is impossible, owing to the pressure in the barrel, the working head in its continued movement causes the rods to yield until the upstroke is begun without an opening of the traveling valve. During this upstroke the working head takes up slack and stretch of the rods and the gases in the barrel expand and partially force the plunger upward. Since neither the traveling valve nor the standing valve has opened during a complete revolution of the driving unit, there has been no flow of liquid from the well into the pump barrel.

This condition continues until the liquid from the strata rises in the well and balances the gas bound pressure in the barrel between the valves. The traveling valve then opens permitting a rapid "heading" discharge without relation to the barrel plunger movement, which only becomes effective after this period ceases. Continued pumping lowers the liquid level in the well and the gas bound condition again occurs, which results in an intermittent discharge at the surface and a varying load upon the working head and its actuating means.

In order to remove the objections before explained, I have provided a system in which the weight of the rods and moving parts are balanced by a pressure of air on water in a storage tank. One-half of the weight of the liquid load, one-half the weight of the friction of the liquid against the wall of the tubing, and one-half the weight of the acceleration forces for starting the liquid flow up the tubing, are also balanced in the storage tank. The remaining load, consisting of one-half the liquid load, one-half the friction load and one-half the acceleration load, is supplied by a pumping machine located inter-

mediate the tank and the power cylinder for the working head.

All these forces from the pressure tank and pumping machine combine to lift the power piston to the top of its stroke, and on its downward movement the liquid, friction and acceleration loads are relieved. The pump then returns the water from the cylinder to the storage tank and in so doing exerts a force equal to the loads which have been balanced by the pressure in this tank. The weight of the parts carried by the piston now exert a gravitational effort which is transferred to the suction side of the pump.

The rapid downward movement of the barrel plunger, due to the failure of its traveling valve to open, as before explained, increases the pressure on the suction side of the pump, and in fact passes through the water pump valves without entering the pump cylinders. The effective forces are thus transferred directly to the storage tank where in turn they can be utilized to transfer their energy back to the cylinders of the driving unit and the power plunger actuated therefrom.

The invention has for an object, to provide a new and improved hydraulic pumping system including a cylinder provided with a load plunger, a balancing chamber under fluid pressure, conduits connecting the cylinder and chamber, a pumping unit communicating with said conduits intermediate the cylinder and chamber, and means for reversing the direction of discharge from said pumping unit to feed to either the cylinder or said chamber.

A further object of the invention is to present a system such as just described in which means are provided to by-pass liquid from the cylinder of the pumping unit when the pressure of liquid from the power cylinder exceeds that in the balancing chamber.

Another object of the invention is to provide in the aforesaid system a pilot valve adapted to be actuated in the plunger movement to control a portion of the pressure liquid acting upon a main valve arranged to reverse the direction of discharge from the pumping unit.

The invention also provides a multiple pump including a plurality of cylinders and pistons having a common driving shaft with the cranks thereof set relative to the flow delivered by the separate pistons in their correlation to the total delivery capacity of the pump.

The invention further provides for the use of a relief valve upon the pump responsive to excess pressure from either the power cylinder or the storage chamber.

The invention also has for an object to control the speed of travel of the plunger in the power cylinder relative to the velocity of the liquid movement therein and to permit the continued movement of such plunger to com-

plete its stroke after the reduction of its speed by control of the feed of the main body of liquid thereto.

The invention further combines with the variable pressures in the power cylinder and storage chamber a compressor for introducing either gas or liquid into the system and actuated by such differences in pressure.

Other and further objects and advantages of the invention will be hereinafter set forth and the novel features thereof defined by the appended claims.

In the drawings Figure 1 is an elevation of the system applied,

Figure 2 is a top plan thereof,

Figure 3 is a side elevation of power unit with parts broken away,

Figure 4 is a front elevation thereof, with parts in section,

Figure 5 is an enlarged section of the base of the valve leg on line 5—5 of Figure 9,

Figure 6 is a section of the lower portion of Figure 5 with the valves in different position,

Figure 7 is a section on line 7—7 of Figure 5,

Figure 8 is a similar view on the line 8—8 of Figure 5,

Figure 9 is an enlarged section on the line 9—9 of Figure 1,

Figure 10 is a longitudinal section of the pumping unit,

Figure 11 is a section on substantially the line 11—11 of Figure 10,

Figure 12 is a like view on the line 12—12 of Figure 10,

Figure 13 is an elevation of the crank shaft,

Figure 14 is an end view thereof,

Figure 15 is an enlarged section of the relief valve,

Figure 16 is a similar view of the speed control,

Figure 17 is a vertical section of the feeding compressor,

Figure 18 is a diagram of the system with the units in upstroke relation, and

Figure 19 is a similar diagram of the downstroke relation on the units.

Like numerals of reference indicate similar parts in the several figures of the drawings.

The system includes four major units in communicating cooperative relation, to-wit: First, the power head disposed over a well and carrying the loads; Second, the hydraulic head pump and its controlling attachments; Third, the pressure balancing chamber; and Fourth, the feeding compressor for either gas or liquid to be introduced into the system.

One form of apparatus for effecting the functions of the invention has been shown and in the description of its structure the units will be considered in the order just mentioned.

The power head is provided with a tubular pressure column 20 and a similar valve column 21 disposed at opposite sides of a well casing 22 and connected at their upper ends by a pressure header 23 which supports a power cylinder 24 in communication with the pressure column 20. The valve column is closed at its upper end by a wall 25 in the header 23 and the lower ends of the two columns are connected by a pipe 26 having a check valve 27 so that the liquid pressure in the column 20 passes into the valve column and is retained therein, see Figure 4.

The cylinder 24 is enclosed at its top by a cap 28 from which an overflow pipe 29 extends downwardly to an extension header 23' having an escape 29' which leads to the foot of the column and permits the escape of any liquid which may pass the packed pressure piston or plunger 30.

From this piston a rod 31 extends through a packing box 32 on the header to a cross head 33 which carries the pump or polish rod 34 extending to the plunger of the working-barrel pump within the well, and not herein shown.

This crosshead is guided in its reciprocations by the slides 35 and 36 upon the opposite columns, and the head supports a coiled spring 37 disposed to engage the base of the header 23 and cushion the upstroke of the piston and crosshead. For the purpose of similarly cushioning the downstroke a spring 38 is supported within the header and surrounds the piston rod to be engaged by the piston at the limit of its downward travel.

As shown in Figures 1 and 4, the pressure column 20 is connected at its base to a foot plate 39 having a suitable coupling for a conduit 40 from a pumping unit to be hereinafter described, and also a coupling 41 for the pipe 26 connecting the columns.

The valve column 21 is supported by a foot plate 42 carrying a casing 43 for the check valve 27 and also a pilot valve sleeve 44 interposed between the column and foot plate. These foot plates are suitably secured to the base 45 of a derrick 46 in proper alignment with the center of the well casing. The columns and cylinder are supported at the upper portion of the derrick by any suitable braces, such as the rods 47 having swivelled connections 47' with the header 23 and extending to the uprights 48 of the derrick.

The structure so far described provides means for applying a pressure liquid to raise the power piston and its load and also store in the valve column a pressure of liquid to actuate the reversing valve of a pumping unit.

For the purpose of controlling this stored pressure the casing 44 is provided with a pilot valve 50 operating within a ported sleeve 51 mounted in the casing and having at one end a guide rod 52 sliding in a packing 53 and at

its opposite end an operating rod 54 extending through a packing 55 and carrying a yoke 56 in engagement with an arm 57 at the lower end of a valve rod 58 disposed vertically parallel to the valve column 21.

The lower end of the rod 58 is seated in a step 59 while its upright alignment is retained by guides 60. The rod has adjustably mounted thereon oppositely extending curved striker arms 61, disposed within the area of the crosshead guide 35 on the valve column, and provided at their free ends with contact rollers 62 aligned to be engaged by the cams 63 projected at opposite sides of the cross head, as shown in Figs. 3 and 9. This provides for actuation of the pilot valve at the up and down limits of travel of the cross head, and such actuation can be varied by an adjustment of the striker arms on the valve rod so that the pilot valve may be shifted before the crosshead reaches its limit of travel.

Referring to Figures 5 to 8 it will be seen that the interior of the valve sleeve is subject to the pressure within the casing or housing 49 from the column and the ports 64 and 65 at opposite ends thereof communicating with passages 66 and 67 respectively, having pipe connections 68 and 68' to either side of a reversing valve upon the pumping unit to be later described. The intermediate port 69 communicates with a passage 70 connected by pipes 71 and 71' with the balancing chamber and the suction manifold 115.

The foot plate 42 is formed with chambers 72 communicating with the passages 63 and 67 and provided with spring closed check valves 73 and adjustable throttle valves 74 by which the flow may be determined. The foot plate is also formed with a chamber 75 open to the column 21 and having a conductor 77 extending to a compressor unit to be further described, and a drain connection 76.

The head pumping unit comprises a plurality of similar cylinders 80 and pistons 81 therein connected to a common crank shaft 82 mounted in the usual manner at base 83 of the engine. An improved connection for these pistons is shown in Figures 10 and 12 and comprises a rod 84 extending upward through a packing 85 at the upper head of the cylinder 80 and carrying a yoke 86 from which depending connectors 86' engage lugs 87 from a cross piston 88 operating in a cylinder 89 having radial ways 90 to receive the lugs. The pitman 91 from this cross head piston is of the usual construction and mounted upon a crank 92 on the shaft 82.

In the practice of driving a plurality of pump pistons from a single shaft these cranks have been previously spaced at equal distances around the axis of the shaft, but it was found that the effort on the cranks was not uniformly distributed and an air chamber was usually

necessary to secure an even flow of liquid from the pump.

I have found that a uniform rate of discharge can be secured without an air chamber by spacing the crank pins around the shaft axis so that the piston to which each crank is connected delivers an amount of liquid which when added to the amounts delivered by the other pistons makes an equal volume of liquid for any point in the crank shaft revolution. The vertical arrangement of the liquid cylinders and the piston driving connections causes any leakage to be caught at the top packing which prevents flooding of the oil at the base and permits an upright pump to be combined with a self-oiling device.

The shaft 82 carries a gear 93 traveling thru the oil bath 94 and meshing with a pinion 95 on the shaft 96 carrying the fly wheel 97 driven by a belt 98 from a suitable motor 99 as indicated in Figure 2. Within the bath or pan 94 rotating oil pump 100 is disposed and driven by a gear 101 meshing with the gear 93 to supply oil at any required point in the pumping unit. This oil pump is mounted upon a cover plate 102 secured at the base, Figure 11, so as to be readily removable when desired.

Each of the cylinders 80 is double acting, that is, provided with a top port 103 and a bottom port 104 and each port is provided with a suction and a discharge valve. The suction valve for the top port is shown at 105 and its discharge valve at 106, while the suction for the lower port is through valve 107 and passage 108 provided with a rib 109 to prevent swirling of the liquid in its rapid flow, and a discharge valve 112. The flow from this valve 112 and valve 106 is by a duct 113 communicating with a discharge manifold 114 common to all the pump cylinders. The suction valves 105 and 107 likewise receive liquid from a manifold 115 and passage 116. This valve arrangement permits liquid to by-pass the pump cylinders when the pressure at the suction side exceeds that at the discharge.

A special construction of the suction and discharge valves is shown in Figure 12, by which the valves are guided in alignment with their seats and their opening retarded in speed by suitable springs. For this purpose the covers 127 for the several valve seats are formed with a depending stud 128 upon which the sleeve 129 from the valve is slidingly mounted, and each valve is retained upon its seat by a spring 130 disposed between the cover and valve.

For the purpose of reversing the flow from the pump to deliver liquid pressure to either the power cylinder or a pressure chamber, to be described, a main valve 120 is mounted on the pump intermediate the groups of cylinders and communicates with the manifolds

just described. The valve 120 has its heads 121 operating in ported sleeves 122 communicating with the manifolds. This valve has a control piston 123 upon its stem 124 and disposed in a cylinder 125 having pressure connections with the pipes 68 and 68' from the ports of the pilot valve and so controls the liquid pressure from the valve column as to actuate the main valve in either direction and thereby change the direction of discharge from the pump manifolds. The heads of the main valve are subject to the pressure in the chamber 126 and thus balanced so as to be easily operated by differentials in pressure.

Since the reversal of pump discharge is for the purpose of cooperating with a balancing chamber and the power piston, the construction of such a chamber will now be described.

As shown in Figures 1 and 18, this chamber comprises a tank 131 adapted to retain a body of liquid at its lower portion and a superposed body of gas under pressure. The tank communicates with the main valve of the pumping unit by a conduit 132 having a valve 132' and extending beneath the liquid level therein and acting alternately to discharge and restore liquid from the tank. The pilot valve is also connected with the lower portion of the tank by a branch pipe 71a connected to the pipe 71 to effect a reduced pressure therein and to the suction manifold 115 by a branch pipe 71' for the purpose of shifting the main valve by pipe 68 for feeding pressure to the power piston or balance chamber as shown by the diagram in Figure 18.

In the pumping operation there is an interval during valve reversal when the liquid has no outlet and damage would result were not this condition relieved, because the heavy loads carried by the plunger head and the kinetic forces of moving parts must be gradually dissipated. This relief is accomplished to some extent by the lead or advance opening given by the ports of the main reversing valve, in which when its faces are in the middle of the ports, a passage for the liquid is provided around the ends of the valve to bypass from the balance chamber to the power head, or vice versa.

It is desirable to further provided a relief valve for this purpose which besides cushioning also functions to relieve the pump from hydraulic strains due to excessive pressure caused by rod breakage, failure to reverse, or other stoppages incident to faulty operation.

This relief valve comprises a body 135 having a connection 136 with the suction manifold of the pumping unit and a connection 137 with the discharge manifold thereof, as shown in Figure 15. The body is provided with a valve seat 138 and cooperating valve 139 formed with a chamber 140, discharging through an orifice 141 into the upper cylinder body 142 of the valve. The inlet to this

chamber 140 is protected by a screen 143 and the upward travel of the valve limited by a stud 144 engaging the pilot valve plate 145 carrying the valve seat 146 of greater area than the orifice 141. A spring 147 is seated on this plate and the valve to normally close the same. Above the valve plate a cover plate 148 is mounted to provide the chamber 149 communicating by a passage 150 with the suction connection 136.

A valve cover 151 is supported upon the plate 148 and forms a pressure chamber 152 having a passage 153 communicating with the discharge connection 137. The plate 148 also carries an upright cylinder 154 in which a valve plunger 155 has a limited reciprocation, its upward travel being limited by a stop nut 156 and the downward travel by a shoulder of an enlarged portion 157, which has a flange 158 at its upper end resting upon the balancing spring 159, the lower end of which spring is supported by a cage 160. This cage is suspended by an open cover 161 having a swivelled connection with the adjusting screw 162 threaded through the valve cover 151 and provided with a holding nut 163 enclosed by a cap 164. An air vent 164' is provided at the upper portion of the chamber 152 and a pressure gage may be applied at the opening 165.

A valve 166 cooperates with the seat 146 and is yieldingly suspended by a stem 167 from the portion 157 of the cylinder. For this purpose a spring 168 is interposed between the head 169 on the stem and a support 170 on the cylinder, all the parts being enclosed by a cover nut 171.

When in the operation of the pump the pressure thereon becomes greater than desired, the excess pressure upon the face of the relief valve plunger forces it with the pilot valve downwardly, permitting liquid above the relief valve to flow to the suction side of the pump, this flow is greater than can come through the relief valve orifice and this valve becomes unbalanced so that the greater pressure upon its under face can raise the relief valve, thus allowing a free flow from the discharge to the suction side of the pump, and relieves the strain on the entire mechanism.

The action is reversed when the pressure upon the discharge side falls, as the balance spring relieved of pressure raises the plunger to close the relief pilot valve which cuts off the flow to the suction side of the pump. The liquid then passes through the unobstructed valve orifice filling the space above the piston end of the relief valve and balances the pressure above and below the same.

The weight of the relief valve and its spring then forces it to its seat to permit the pump to operate as before being relieved. The balance spring equalizes the pressure difference between the upper part of the plunger exposed to discharge pressure and the low-

er side of the plunger exposed to suction head pressure, and this difference can be adjusted by the threaded stud supporting the spring cage. The relief valve thus provides means for automatically releasing pressures which is an important feature in pumping mechanism subjected to varying loads.

Under certain conditions, such as lightening the load by the breakage of the sucker rods of a well, some means are necessary to prevent the pressure from the balance chamber and pump from driving the power plunger upwardly at a dangerous speed. For this purpose and for controlling the speed at which the pump operates, a speed control valve is installed in the pipe leading from the main valve of the pumping unit to the power head. This valve is designed to reduce the speed at which the plunger can safely work by taking advantage of the frictional resistance occurring when there is a change in velocity of a moving column of liquid.

The novel structure of this speed control valve, as shown in Figure 16, comprises a pipe section 172 having an annular valve seat 173 cooperating with a valve 174 slidably mounted upon a stem 175 and having a conical pressure face 176 disposed in the direction of fluid flow. This face is formed with vent openings 177 to permit a continuous limited flow therethrough when seated, and is normally held away from its seat by a spring 178 engaging a shoulder 179 on the stem and the inner face of the valve. The inner end of the stem is supported by a spider 180 and its outer end adjustably threaded through a head 181, whereby the tension of the spring may be adjusted to determine the velocity required to close the valve.

The spring and stem are enclosed within a casing 182 carried by the head and extending into the valve with a clearance therefrom to permit passage of liquid entering the valve through the vent openings. In case of spring breakage this casing prevents entry of broken parts into the rest of the apparatus.

When set for a predetermined velocity of liquid flow the speed control valve is not disturbed in position, but an increase in such velocity produces a resistance at the pressure face of the valve which overcomes the spring and closes the valve which slows down the movement of the power plunger to prevent damage. A sudden stoppage of this flow would prove injurious to the mechanism, so that the vent holes permit sufficient flow of liquid to carry the plunger to the top of its stroke at a slow speed, and the movement of the plunger is then reversed by a change in the direction of flow. Upon such reversal the spring retracts the valve

from its seat and the parts operate in the usual manner.

The system also includes an improved compressor actuated by differences in fluid pressure under operating conditions for the pressure cylinder and balancing chamber, and designed to introduce either liquid or gas into the system, and also to compensate for losses thereof incident to operation.

The construction shown in Figure 17 comprises a pressure cylinder 185 having a connection 186 at its base with the line 40 from the pumping unit, and a head 187 at its top with a connection 188 communicating with line 71 and the balancing chamber 131. This head supports a feeding cylinder 189, of substantially one-half the diameter of the cylinder 185, and within these cylinders a large packed piston 190 and a smaller packed piston 191 operate and are connected by a common rod 192. The cylinder 189 is provided at its upper end with a valved liquid feed pipe 193 and a valved air feed line 194, both controlled by a suction valve 195, in the head 196. At the opposite side of the head a discharge valve 197 is disposed and delivers to the liquid pipe 198 extending to the balancing tank, or to the air line 199 leading to the valve column connection 77 and the tank at 200, Figure 1.

In the operation of the compressor, consider the power plunger at the well head on the beginning of its upstroke, both of the compressor pistons down and a load of fluid above the small piston 191. The pressure from the balance tank is upon the top of the large piston and the bottom of the smaller piston, but the large piston is also subject to the discharge pressure on the lower side generated by the pumping unit to lift the load and this pressure is greater than that on the upper side of the large piston received from the balance tank. This pressure difference carries the compressor pistons upward to discharge either liquid or air above the small piston into the balance tank or valve column as desired.

The reversal of travel of the power plunger involves discharging from the pumping unit into the balancing tank which increases the pressure therein transmitted to the compressor pistons which move downward on a suction stroke as the pressure from the power plunger is reduced. The weight of the pistons and rod, plus the pressure from the balance tank, thus effects a positive reciprocation of the compressor pistons controlled by the pressure variations incident to the reversal of the discharge from the pumping unit.

It is believed that the general operation will be obvious from the foregoing description, and in Figures 18 and 19 diagrams are given of the essential parts, omitting the attachments such as the relief valve, speed control, and compressor. These diagrams give the

relative valve positions, those in Figure 18 being for the up or working stroke of the power head when the pump unit is discharging thereto, and in Figure 19 the valves are shown for the reversed pump discharge to the balancing chamber.

Under starting conditions it is desirable to allow the exhaust water from the pilot valve to pass through pipe 71 into the suction manifold, and the feed of such water to the balance chamber only begins after starting and when the plunger head is in full operation. The pipe lines for this purpose are provided with suitable valves for properly directing the exhaust water from the pilot valve under different conditions of use.

An important feature of the invention is the arrangement of check valves 73 and the throttle valves 74 to reverse the motion of the head plunger slowly or quickly as load conditions may require. This is accomplished by regulating the amount of water flowing from the column leg 21 and to the control piston 123, and allows the liquid to flow in one direction uninterrupted by the throttle valve of one pipe and in the other pipe uninterrupted by the throttle valve of the first mentioned pipe. Both of these valve groups are affected by the movement of the control piston 123 and if the water were not by-passed around the throttle valves by the check valves individual regulation of the reversal intervals of the plunger head could not be secured. Since the load conditions are different at the top and bottom of the stroke it is necessary to provide such means for independently regulating the reversal at either end of the stroke.

It will be seen that the balancing chamber, pumping unit and power head are placed in series connected by piping and in beginning operations about three feet of liquid is placed in the balancing chamber, while air or gas is also forced therein until the pressure will sustain the weight of the sucker rods, all moving parts of the head, and the working barrel plunger in the well. An added pressure of air or gas is then forced into the chamber until there is an energizing force therein equal to one-half the weight of the oil head to be lifted, one-half of the resistance head due to the friction of the oil pumped through and against the walls of the tubing leading to the surface and the friction of moving parts, and one-half of the force necessary to accelerate the dead weight of the oil and keep it flowing up the tubing.

To complete the pumping it remains to generate with the hydraulic pump sufficient energy to lift the remainder of the oil, friction and acceleration loads. The liquid in the balance chamber under the pressure existent therein can flow freely through the valves of the hydraulic pump to the underside of the plunger in the head above the

well. The motor being started the pump draws liquid from the balance chamber to fill the piston cylinders which force the liquid through the discharge and control valves to the plunger head. The combined energy of the balance chamber and that developed by the pump is sufficient to lift the plunger with its attendant moving parts and the oil, friction and acceleration loads. The plunger is thus moved upwardly and at the same time liquid under the same pressure is forced into the valve column and retained by the check valve to supply energy to operate the main or control valve.

At a suitable point in the upstroke the cam on the cross head shifts the pilot valve to admit a quantity of liquid against the lower side of the control piston of the main valve, while at the same time ports permit the liquid above the control piston to return either to the suction side of the pump or to the balance chamber. The main valve moves upwardly under these influences and thus reverses the direction of flow of the liquid discharged by the pump pistons to feed the balance chamber and restore the pressure therein.

The pressure required in the balance chamber to sustain all the loads before mentioned amounts in practice for a 5000 foot pump setting and a two and one-half inch plunger, to approximately 300 pounds per square inch. The additional pressure to lift the balance of the load and which must be developed by the pump amounts to approximately 120 pounds per square inch, making a total of 420 pounds per square inch.

As the flow is reversed, all the oil load, friction and acceleration loads are automatically removed, but this is in theory only as in practice the gas between the traveling and standing valves of the working barrel in the well, prevents the traveling valve opening so that its plunger still has all the oil load on its upper side. This causes a very rapid downward movement of the plunger and parts carried thereby until a point is reached where the traveling valve will open. This downward force is greater than the pressure in the balancing chamber and the liquid under pressure from the plunger of the head passes through the valves of the pump without propulsion by the pistons thereof.

Varying conditions of pressure are thus cared for and this attribute remedies the conflict between the working barrel plunger and the driving mechanism or pump before described. The downward movement of the head plunger continues until either the traveling valve opens or the momentum is overcome by the rising pressure in the balance chamber.

When the traveling valve has opened there remains only the weight of the rods and moving parts upon the head plunger and this amounts to approximately 176 pounds per

- square inch. The balance chamber has a pressure of 300 pounds per square inch existing therein and before it can receive liquid from the head plunger the pump must generate the difference of approximately 124 pounds per square inch. The pump withdraws from the cylinder of the head the liquid which is forced to that point on the upstroke.
- It will be seen that the pump must generate substantially the same energy for both the up and down strokes and insures an even and continuous operation and flow. The pump always works against a constant pressure and the demand on the driving motor or engine is a constant factor. In the functioning of the system the pressure per square inch on the plunger head side of the pump varies from 176 to 420 pounds, while the pressure per square inch in the balancing chamber varies approximately 20 pounds. When the plunger reaches the downward limit of its stroke the main valve is reversed by the cam and pilot valve connections and the head plunger again starts its upward stroke.
- The method involved consists in withdrawing liquid from the balancing chamber, forcing it into the plunger of the head, reversing the flow, and forcing the liquid from the head to the balancing chamber. The varying of the load due to greater depth of oil, sand or excess gas is quickly compensated for by the arrangement of the units and the attachments provided for relieving the pressure, controlling the speed of flow, and operation of a compressor by the different pressures to feed either gas or liquid to the system. There are no large moving mechanisms of great weight to generate kinetic energies at variance with the rest of the moving parts, and consequently no shocks in operation, but a smooth, powerful and noiseless pumping to raise the liquid from greater depths with a minimum of operating expense and trouble.
- Certain units have been described as parts of the system but they may be varied to suit different conditions of use, and while the specific construction of these units has been shown and described the invention is not confined thereto as changes and alterations may be made therein without departing from the spirit of the invention as recited in the following claims.
- What I claim, is:
1. In a hydraulic pumping system, a load lifting unit comprising parallel pressure columns connected at their upper ends by a head, a cylinder mounted upon said head and communicating with one column, a pumping unit for supplying fluid to the column connected to said cylinder, a conduit connecting said columns, whereby a portion of the fluid supplied by said unit flows into the other column, a fluid system connected to said other column, a valve controlled by said system for affecting the operation of said pumping unit, and a working plunger disposed in said cylinder and having a rod depending parallel to said columns.
 2. The hydraulic pumping system defined by claim 1, and a cross head upon said rod engaging slides on the opposite columns, and cushioning means between the head and the plunger and cross head.
 3. The hydraulic pumping system defined by claim 1 in which is provided a reversing valve associated therewith having a control piston, a pilot valve for controlling the flow of fluid from said other column to opposite faces of the control piston, and means on said rod for actuating the pilot valve adjacent the end of each plunger stroke.
 4. In a hydraulic pumping system, a load lifting unit, a pumping unit communicating therewith, a balancing chamber communicating with the pumping unit, a feeding compressor for supplying fluid and air to the system, said compressor including superposed cylinders of different capacity, connected pistons operating in said cylinders, suction and discharge connections at the top of the upper cylinder, a conduit connecting the top of the lower cylinder with the balance chamber, and a conduit connecting the bottom of the lower cylinder with said lifting unit whereby the variations in pressure at the lifting unit and pressure chamber cause reciprocation of the compressor pistons.
 5. In a hydraulic pumping system, a cylinder provided with a load plunger, a pressure balancing chamber containing fluid under pressure, conduits connecting the chamber and cylinder, a pumping unit connected in said conduits between the chamber and cylinder, liquid operated means for reversing the direction of discharge from said unit to deliver liquid under pressure to either said chamber or cylinder whereby fluid flows from said chamber and to said cylinder or from said cylinder and to said chamber, and a feed compressor connected to the chamber for supplying fluid under pressure thereto, and having a piston arranged to be actuated by differences in fluid pressure in said chamber and cylinder during continued operation.
 6. In a hydraulic pumping system, a cylinder provided with a load plunger, a pressure column communicating with said cylinder, a fluid column communicating with the pressure column, a pilot valve connected with the fluid column and controlled by the displacement of liquid by the plunger, a pumping unit connected to the pressure column, a pressure balancing chamber connected to said pumping unit and a reversing valve for controlling the flow of liquid and caused to actuate by the pilot valve, said reversing valve being arranged to establish the flow of liquid between the pumping unit and the balancing chamber or between said unit and the pressure column.

7. A hydraulic pumping system as defined by claim 6, and valves for the cylinders of said pumping unit arranged to by-pass an excess of liquid pressure from the load
5 plunger to the balance chamber.

8. A hydraulic pumping system as defined by claim 6, in which a valve rod is arranged parallel the fluid column and provided with
10 striker arms and an arm engaging the pilot valve, and a cross head carried by said plunger and provided with cams to contact with said striker arms.

In testimony whereof I affix my signature.
WILLIAM E. HUBBARD.

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