

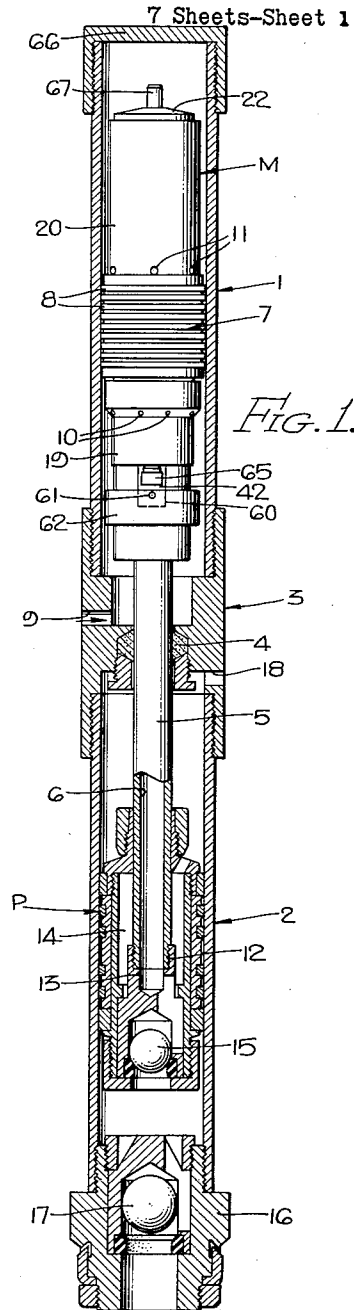
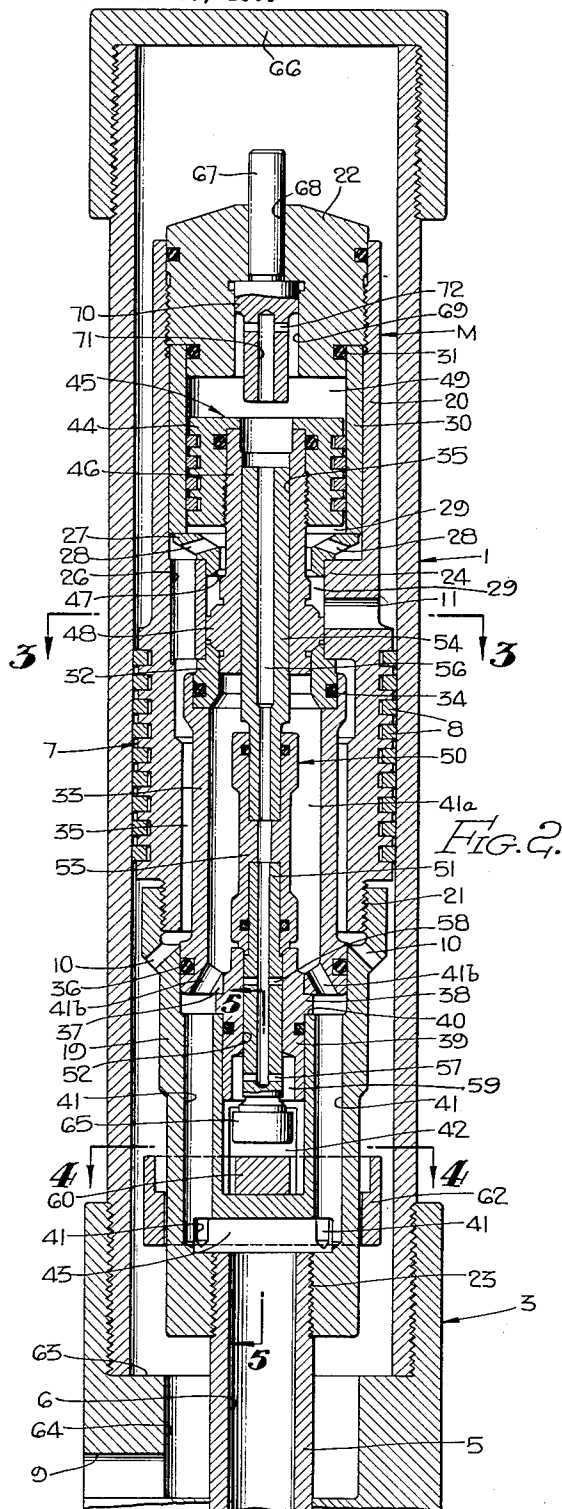
May 9, 1961

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2,983,227

FLUID PRESSURE OPERATED ENGINE FOR WELL PUMPS

Filed June 15, 1959



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FLUID PRESSURE OPERATED ENGINE FOR WELL PUMPS

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7 Sheets-Sheet 2

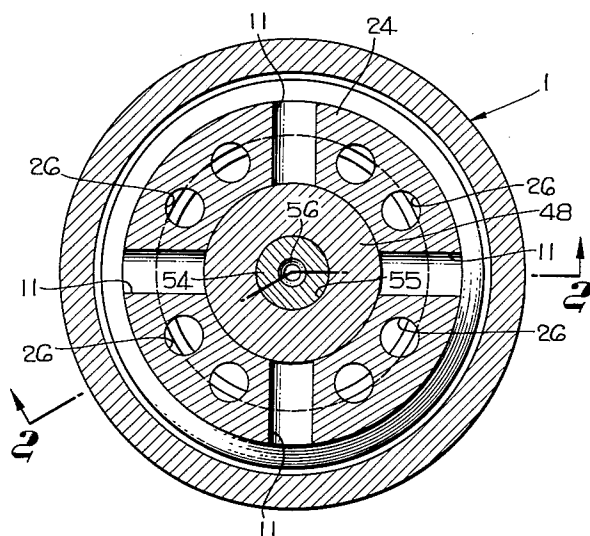


FIG. 3.

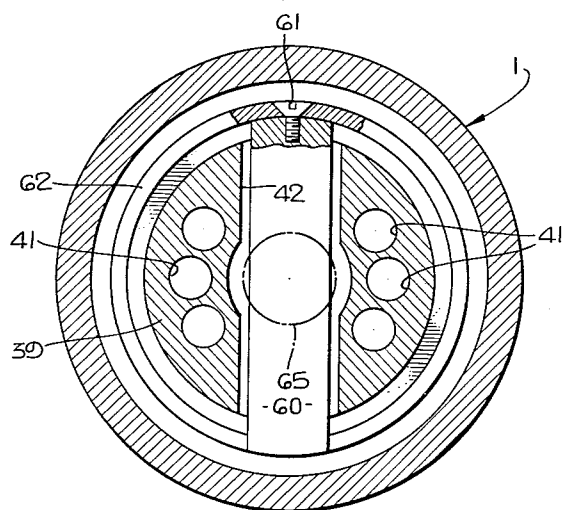


FIG. 4.

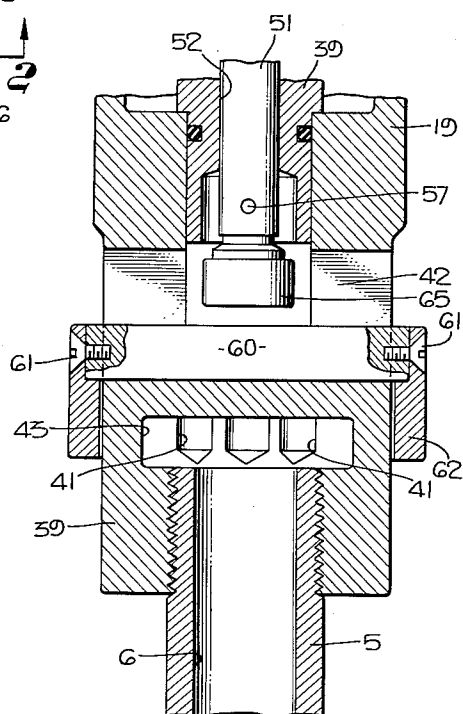


FIG. 5.

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7 Sheets-Sheet 3

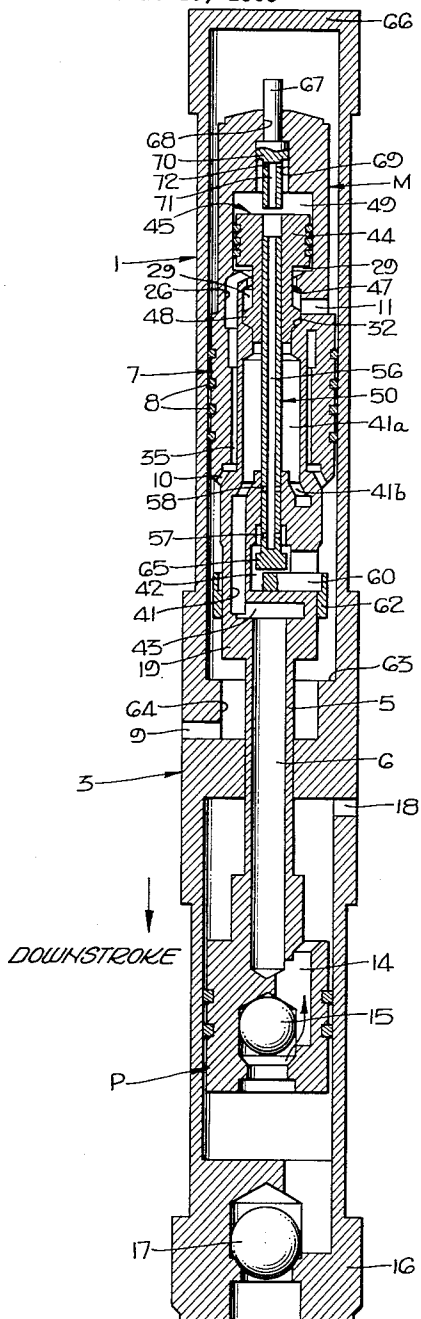


FIG. 6.

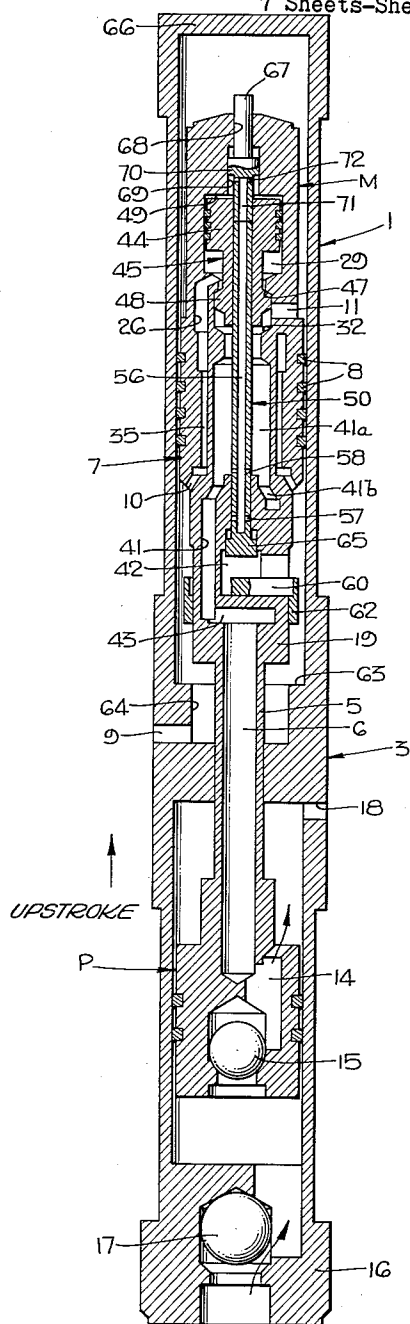


FIG. 7.

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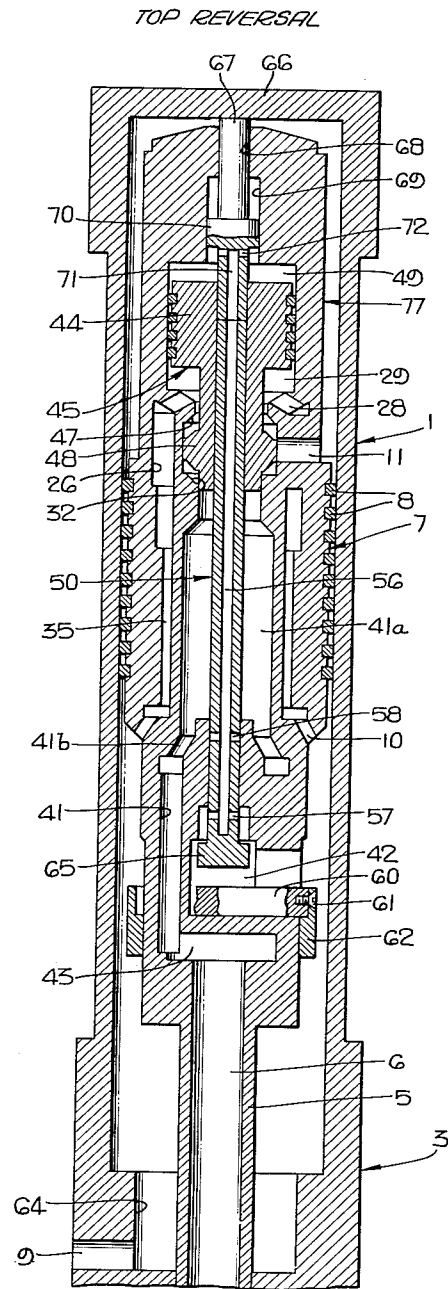
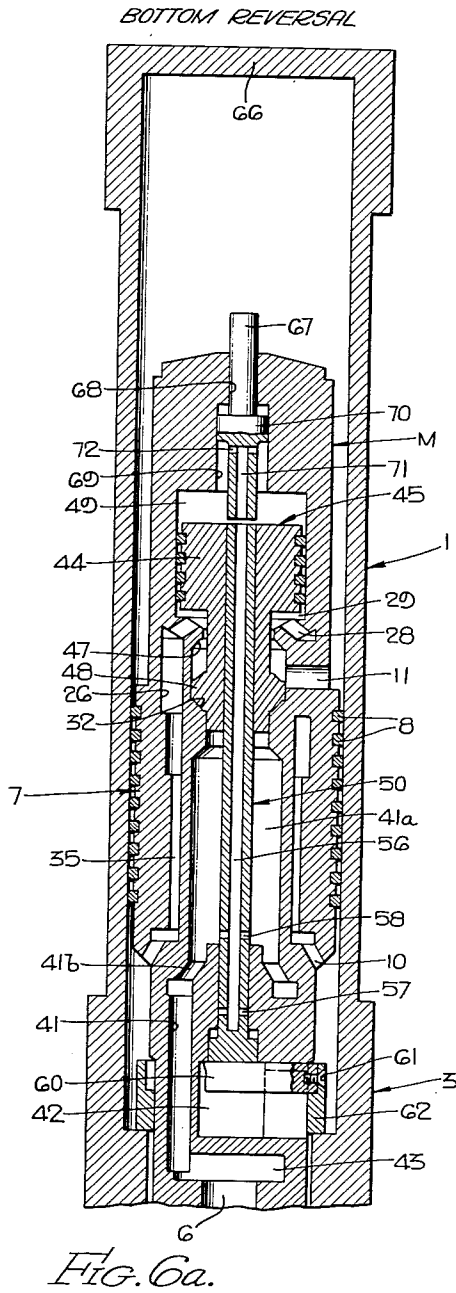
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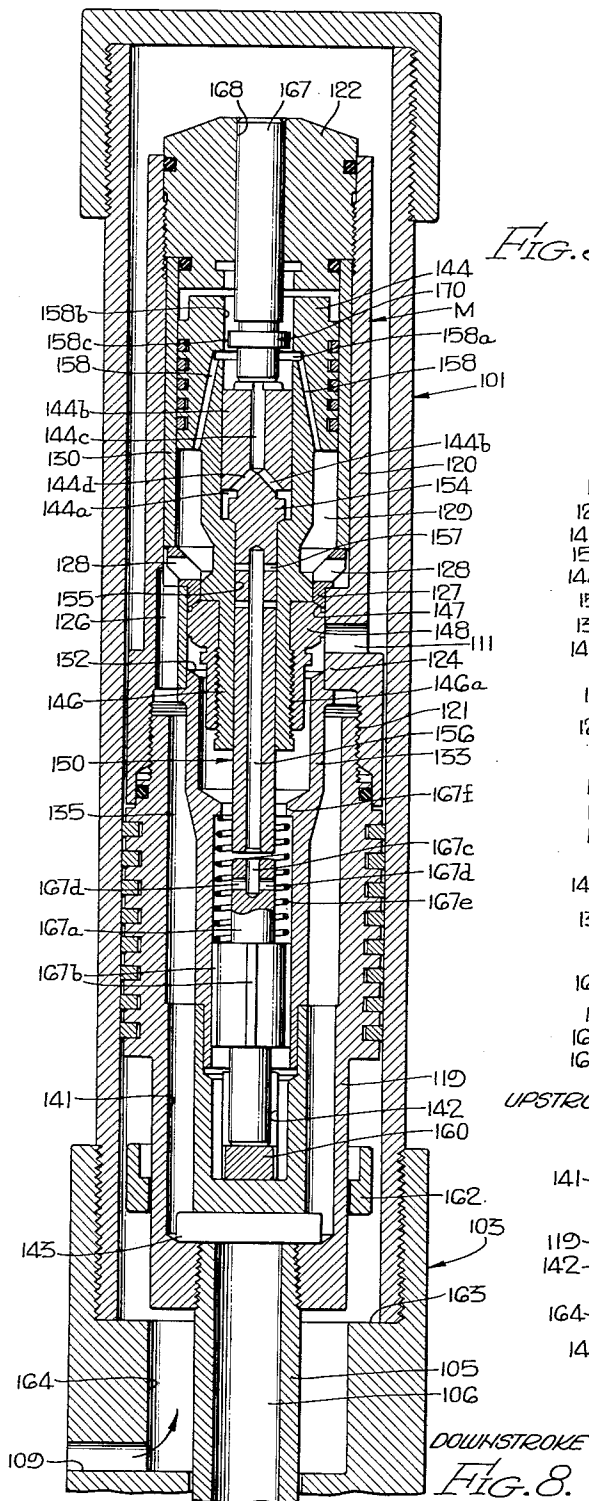
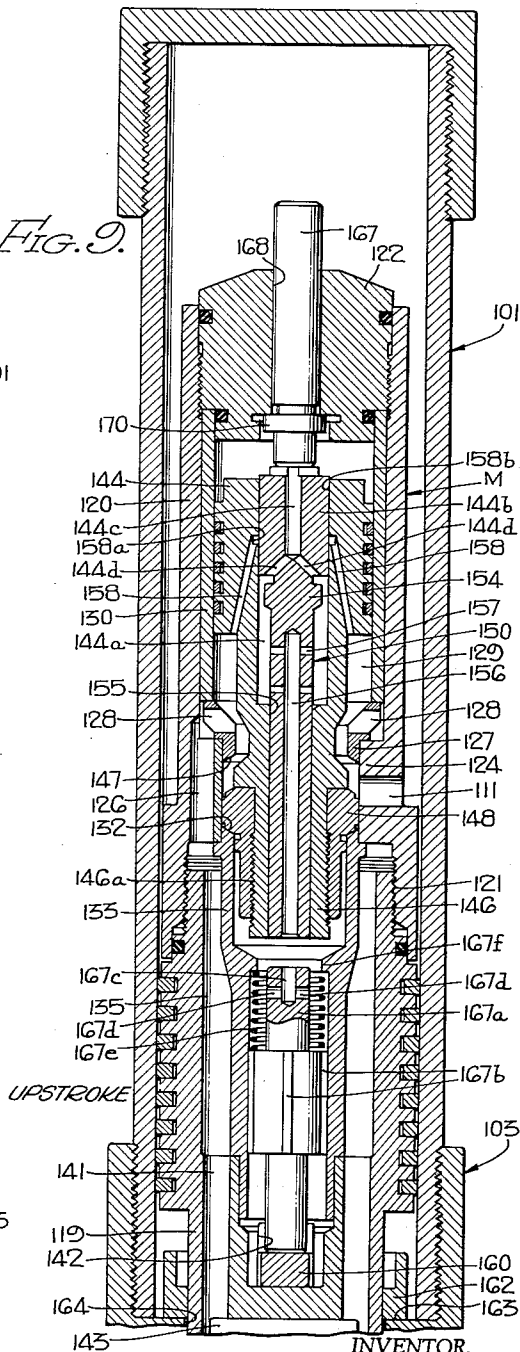


FIG. 9.



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FLUID PRESSURE OPERATED ENGINE FOR WELL PUMPS

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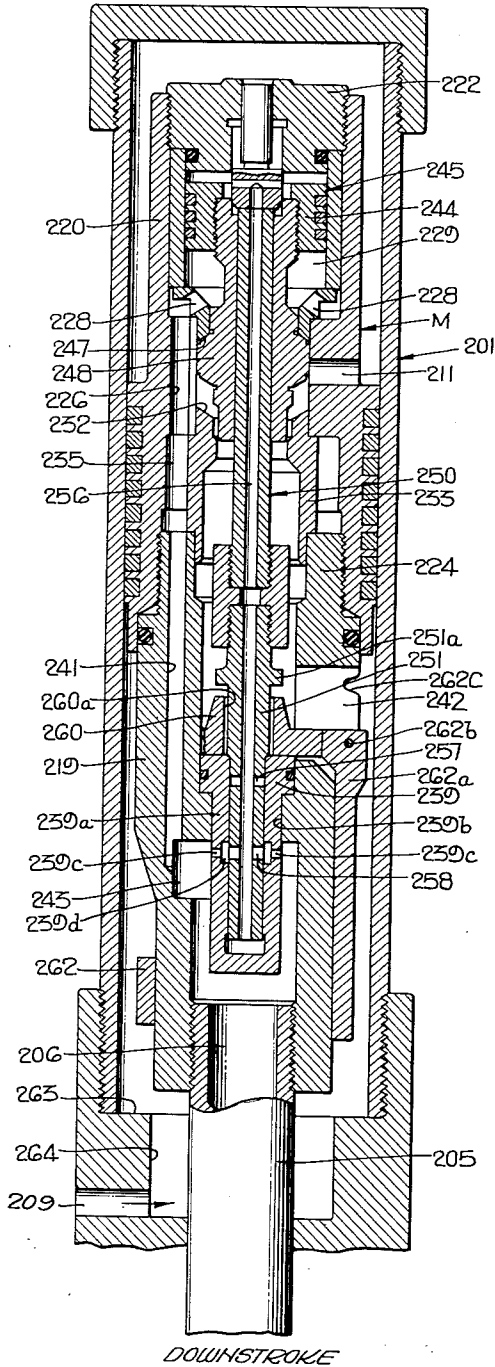


FIG. 10.

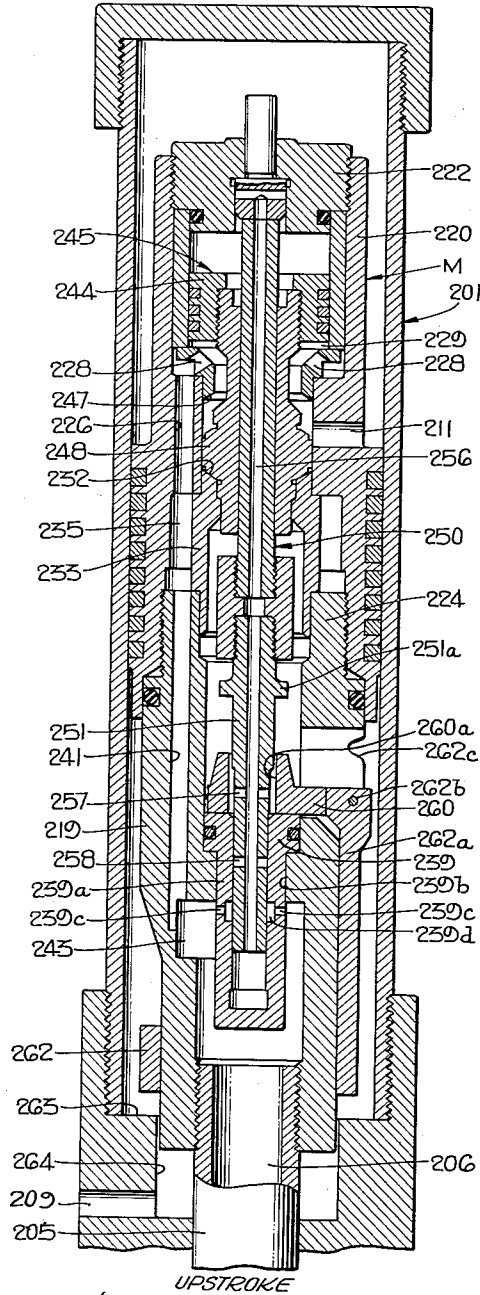


FIG. 11.

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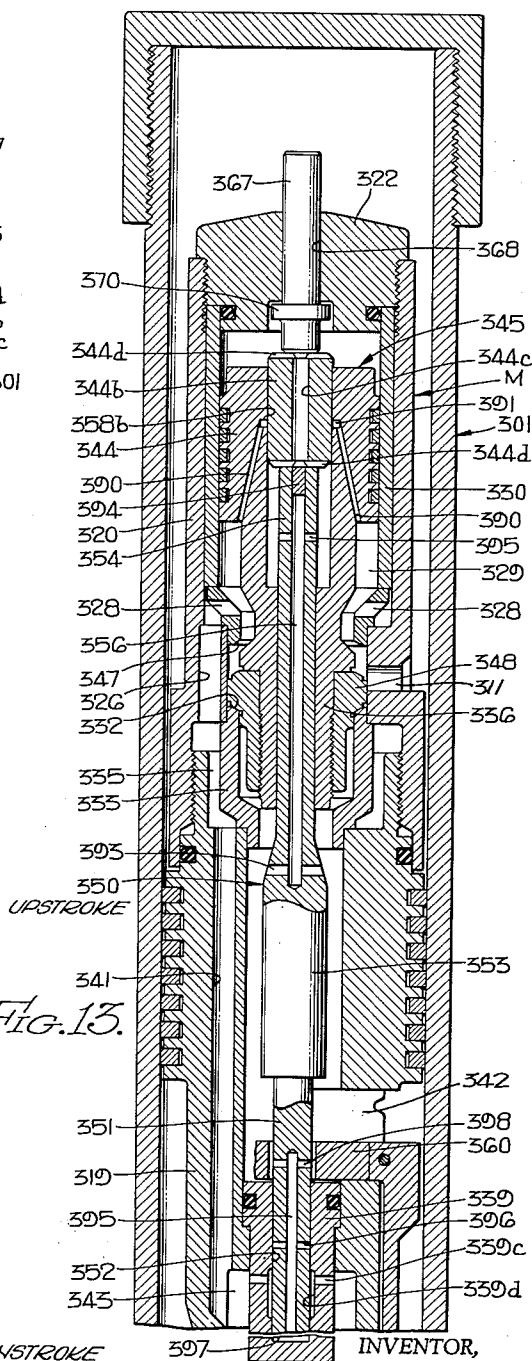
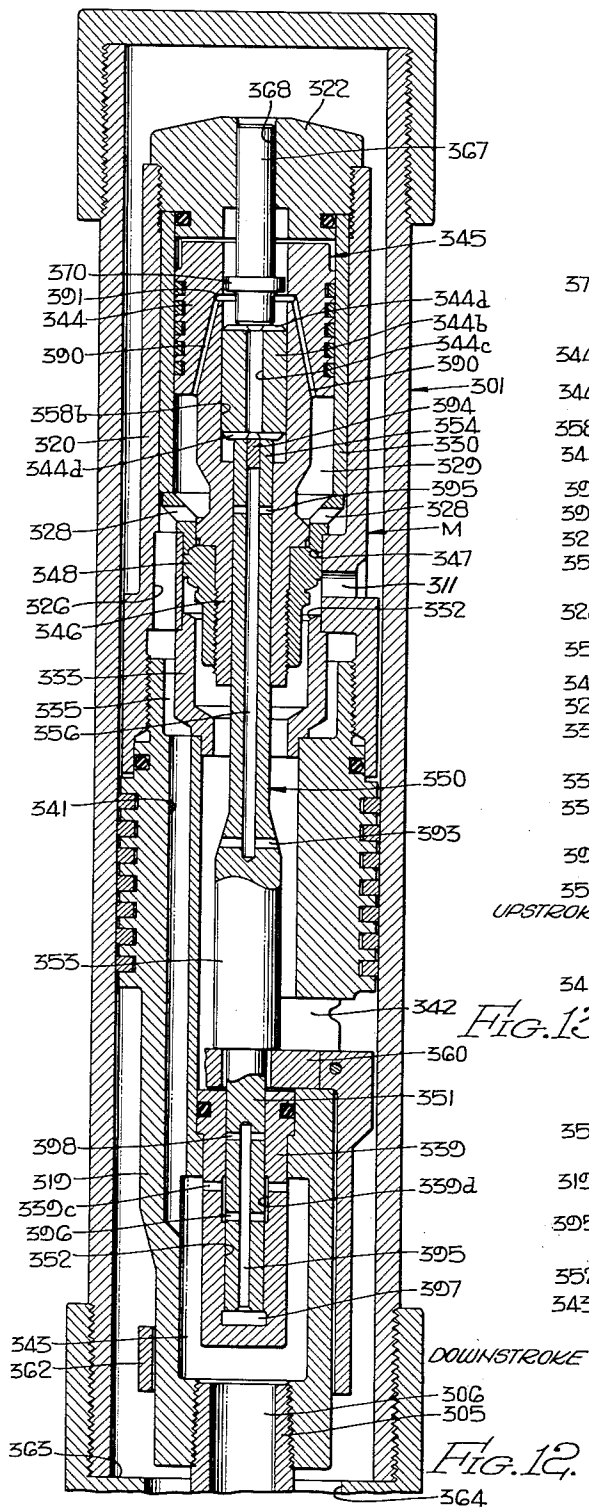
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FLUID PRESSURE OPERATED ENGINE FOR WELL PUMPS

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7 Sheets-Sheet 7



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FLUID PRESSURE OPERATED ENGINE FOR WELL PUMPS

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Filed June 15, 1959, Ser. No. 820,305

21 Claims. (Cl. 103-46)

The present invention relates to engines for reciprocating well pumps, and more particularly to an improved fluid pressure operated reciprocating piston engine adapted to be disposed in an oil well for effecting reciprocation of a pump travelling valve of a single acting pump.

Specifically, the invention contemplates improved valve mechanism for controlling the flow of operating fluid under pressure from a source, to an engine cylinder in which is reciprocably disposed an engine piston connected to a combined pump operating rod and engine cylinder exhaust conduit, such combined operating rod and exhaust conduit extending through a packing gland into a pump chamber. Under the control of the valve mechanism, operating fluid pressure will effect reciprocation of the engine piston and consequently the combined pump operating rod and exhaust conduit, thus effecting operation of the pump.

One well known type of fluid pressure operated reciprocating well pump includes elongated engine and pump cylinders arranged end-to-end and spaced apart by a packing gland or middle plug through which extends a hollow so-called middle rod or combined operating rod and exhaust conduit. Within the pump cylinder, the middle rod is connected to a single acting, valved pump piston, upward movement of which will lift fluid through a production conduit leading to the top of the well, while well fluids are drawn into the pump cylinder through a standing valve. Upon downward movement of the pump piston fluid in the pump cylinder between the pump piston and the standing valve will pass through the travelling valve in the piston into the pump cylinder above the valve.

Such reciprocation of the pump piston is effected by appropriate application of power fluid supplied under pressure to the engine cylinder and imposed at all times upon the lower end of the engine piston so as to bias the engine piston upwardly in a power stroke, while the upper end of the engine piston is subjected to exhaust pressure principally, the hydrostatic pressure of fluid in the production tubing leading to the top of the well, which is less than the operating fluid pressure. Valve means are employed to alternately close off the communication between the upper end of the engine cylinder and the exhaust conduit and to admit the aforementioned operating fluid pressure to the upper engine cylinder. The effective fluid pressure responsive end area of the upper end of the engine piston is greater than the effective fluid pressure responsive area of the lower end of the engine piston by the cross-sectional area of the middle rod, so that when operating fluid pressure is imposed on both ends of the engine piston a down stroke will occur as a result of a net force in a downward direction.

Control of the valve means for reversing the porting so as to alternately apply operating fluid pressure to the upper engine cylinder and to exhaust the latter, has heretofore been accomplished by means of a pilot valve coaxially extending into one end of a reciprocating dif-

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ferential end area main valve piston, and adapted to vary the pressure conditions acting on the main valve piston end areas to shift the main valve in opposite directions to reverse the porting. The main valve is coaxially disposed in a valve chamber within the engine piston. Actuation of the pilot valve has been effected by means of a long thin trip rod extending into the main valve chamber through the upper end of the engine piston, such trip rod extending through an abutment spaced from the engine cylinder, and having spaced stops alternately engageable with the abutment to shift the pilot valve and thus effect actuation of the main valve as the engine piston approaches the end of its movement in opposite directions in the engine cylinder.

The aforementioned type of fluid pressure operated pump has proven to be effective under more or less favorable well conditions, i.e. conditions of non-gassy well fluids and where the reservoir of well fluids is not pumped off. However, serious failures have resulted in many instances where unfavorable gassy and/or pumped-off conditions are encountered. In addition, the manufacture and assembly of such prior fluid pressure operated pumps, where long trip rod pilot valve actuation is required, pose various difficulties. Principal among service failures is failure of the trip rods under pumped-off or gassy well conditions, when the pump cylinder contains large quantities of gas and movement of the engine piston is at such a rate and with such force that tripping of the pilot valve results in undue strain on the trip rod and ultimate failure.

In accordance with the present invention a fluid pressure operated engine is provided wherein the engine piston has a main valve chamber coaxially therein, in which the reciprocating main valve is disposed, there being a pilot valve concentrically disposed in the engine piston and passing entirely through the main valve. In such a construction the pilot valve is so constructed that the pilot valve ports are opened or closed by reason of the pilot valve being shifted longitudinally relative to the engine piston and main valve piston within the confines of the engine cylinder. Clearly, therefore, a more compact, easily manufactured engine assembly is provided, wherein no trip rod need be provided and the characteristic trip rod failure is obviated while other economies are realized.

A principal object of the invention, then, is to provide a compact, serviceable fluid pressure operated engine for reciprocating well pumps, wherein the engine comprises an engine cylinder in which is concentrically disposed an engine piston having a main valve chamber extending coaxially therein, there being a main valve piston shiftable in said chamber to first and second positions for reversing porting in said engine piston, whereby one end of the engine cylinder is alternately subjected to operating fluid pressure and exhausted, while a pilot valve extends coaxially in the engine piston and through the main valve piston, the pilot valve being engageable with abutments in the engine cylinder at opposite ends of the engine piston so as to be shifted relative to the engine piston and the main valve, thus to alter the pressure conditions acting on the main valve piston to effect movement of the latter and reversal of the direction of movement of the engine piston.

Yet another object is to provide a reciprocating engine structure in accordance with the principal objectives heretofore, wherein a top pilot valve shift is produced by effective engagement of the upper extremity of the pilot valve with the top of the engine cylinder. Specifically in this connection, the invention contemplates a top pilot shifter which shiftablely extends through the top of the engine piston and has an external area subjected to power fluid pressure during downstroking of the engine piston, where-

in the top pilot valve shifter is provided with a head slidable in an elongated bore for effecting a dash-potting or retardation of movement of the shifter into and out of the engine cylinder, thus to prevent a sudden variation in the volume of the upper valve chamber at the upper reversal and to minimize damaging impact of the pilot shifter with the pilot valve stem and with the piston head.

Still another object is to provide an engine as aforementioned having a main valve and pilot valve construction and porting which are so related as to assure complete or effective pilot controlled main valve reversal prior to reversal of movement of the engine piston to such a substantial extent that oscillation will result from engine piston reversal taking place prior to the completion of the pilot valve and main valve reversal.

In the accomplishment of the various aforementioned objectives, as well as others, the invention contemplates the provision of a fluid-actuated deep well pump including, in a combination, a double-acting motor having a differential end area motor piston interconnected by a hollow rod, with a pump piston reciprocable in a pump cylinder axially aligned with the motor cylinder. The engine cylinder is ported to enable continuous access of operating fluid under pressure to the smaller end of the motor piston, while as a function of cooperative main and pilot valve means the larger end of the motor piston is alternately subjected to power fluid pressure and to exhaust pressure by reason of the establishment of intercommunication between the motor cylinder at the larger end of the motor piston and the hollow piston rod interconnecting the motor and pump pistons.

Specifically, the invention contemplates an improvement in the just-noted pump motor combination, wherein the main valve means is fluid-pressure-operated and is disposed concentrically in the motor piston, the pilot valve means being concentrically disposed in the motor piston and extending through the main valve so as to control the fluid pressure responsive operation of the main valve to effect shifting of the latter, there being abutment means at opposite ends of the motor cylinder for shifting the pilot valve.

In such a construction the pilot valve is provided with ports which alternately establish communication between a valve chamber at one end of the main valve piston and a source of fluid under pressure, and a passageway which communicates with the opening through the hollow piston rod. The pilot valve ports may be so arranged in the pilot valve stem with respect to a bore in which the stem is slidable that the pilot valve ports are alternately opened and closed so as to alternately communicate with power fluid, which is directed to one end of the main valve, or to be subjected to exhaust pressure whereby to relieve said end of the main valve from power fluid pressure, so that the main valve will be shifted in the other direction through the action of power fluid acting on said opposite end of the main valve. Moreover, the main valve may shift in the direction that the engine piston shifts in order to reverse the engine piston control porting, or the main valve may shift in a direction opposite to the direction of movement of the engine piston, as will more particularly appear hereinafter in the description of the several embodiments of the invention herein disclosed.

In the foregoing as well as in the ensuing description, reference to direction such as "top," "upstroke," "bottom," "downstroke" and other related terminology is with respect to the illustrative embodiments of the invention, and such terms are not to be taken in a limiting sense. In addition, reference to "hydraulic force" or "hydraulic pressure" as applied to the various pressure responsive elements for effecting movement of the elements is to be understood as meaning, unless otherwise qualified, a "net hydraulic force" working in an indicated direction due to similar pressure being applied to differential areas or due to differential pressures being applied to like areas.

Other objectives and advantages of the invention will be hereinafter described or will become apparent to those skilled in the art, and the novel features of the invention will be defined in the appended claims.

Referring to the drawings:

Fig. 1 is a view partly in elevation and partly in section, showing a fluid-pressure-actuated well pump made in accordance with the invention;

Fig. 2 is a vertical sectional view through the engine cylinder and engine piston of the fluid-pressure actuated pump of Fig. 1, this view being taken substantially on the compound plane of the line 2—2 of Fig. 3;

Fig. 3 is a transverse sectional view as taken on the line 3—3 of Fig. 2, and on a slightly enlarged scale;

Fig. 4 is a transverse sectional view as taken on the line 4—4 of Fig. 2, and on a slightly enlarged scale;

Fig. 5 is a fragmentary vertical sectional view as taken on the line 5—5 of Fig. 2;

Fig. 6 is a diagrammatic longitudinal sectional view of the fluid-pressure-actuated pump of Fig. 1, illustrating the condition of the main and pilot valve means during downstroking of the engine piston and on the discharge phase of the pump;

Fig. 6a is a diagrammatic fragmentary longitudinal sectional view showing the engine of Fig. 6 with the pilot and main valves shifted as at the bottom reversal of the engine piston;

Fig. 7 is a diagrammatic longitudinal sectional view of the fluid-pressure-actuated pump of Fig. 1, illustrating the condition of the main and pilot valve means during upstroking of the engine piston and on the suction phase of the pump;

Fig. 7a is a diagrammatic fragmentary longitudinal sectional view showing the engine of Fig. 6 with the pilot and main valves shifted as at the top reversal of the engine piston, but just prior to the existence of a downstroking pressure condition;

Figure 8 is a longitudinal sectional view through a modified form of engine construction with the main and pilot valve means in condition for effecting a downstroke of the engine piston;

Fig. 9 is a view corresponding to Fig. 8 but showing the main and pilot valve means in a condition for effecting an upstroke of the engine piston;

Fig. 10 is a longitudinal sectional view through a further modified form of engine construction with the main and pilot valve means in condition for effecting a downstroke of the engine piston;

Fig. 11 is a view corresponding to Fig. 10, but showing the main and pilot valve means in a condition for effecting an upstroke of the engine piston.

Fig. 12 is a longitudinal sectional view through another form of engine construction with the main and pilot valve means in condition for effecting a downstroke of the engine piston;

Fig. 13 is a view corresponding to Fig. 12 but showing the main and pilot valve means in a condition for effecting an upstroke of the engine piston.

Referring to Fig. 1, the exemplary fluid-actuated pump comprises axially aligned motor and pump cylinders 1 and 2 respectively, threadedly interconnected at their adjacent ends by a so-called middle plug 3, having therein a packing 4 through which extends a hollow middle rod 5 which, as will hereinafter appear, constitutes a combined piston rod and discharge conduit having a passage 6 extending completely therethrough.

Reciprocally disposed in the engine cylinder 1 is a motor or engine piston—generally designated M, which is interconnected by the middle rod 5 with a pump plunger or piston generally designated P. The engine piston M has an enlarged central section 7 slidably and sealingly engaged with the engine cylinder as by means of a suitable number of piston rings 8. Leading into the engine cylinder 1 through the middle plug 3 is a suitable number of power fluid inlet passages 9, whereby power

fluid under pressure is constantly supplied to the lower portion of the engine cylinder beneath the enlarged central section 7 thereof. Such power fluid is adapted to pass into the engine piston body through a suitable number of ports 10 disposed about the engine piston below the enlarged central section 7, and under the control of valve means which will hereinafter be particularly described, such power fluid is alternately enabled to bypass the enlarged central section 7 of the engine piston and enter the upper portion of the engine cylinder through a suitable number of radial ports 11.

Such valve means is also adapted, responsive to the engine pistons reaching the lower limit of its movement, to exhaust fluid from the upper section of the engine cylinder through the ports 11, and thence into the combined piston rod and discharge conduit or middle rod 5, where such exhaust fluid will be co-mingled with fluid being discharged from the pump cylinder 2 during upstroke of the engine piston. Thus the middle rod 5 is threaded into the pump piston P as at 12, and communicates with a bore 13 in the pump piston, which in turn communicates with a production fluid passage 14 extending through the pump piston P.

The pump piston includes a suitable travelling check valve such as a ball check valve 15, while at the lower extremity of the pump cylinder 2 there is a bottom plug 16 having therein a ball or other suitable check or standing valve 17.

Accordingly, it will be noted that an upstroke of the engine piston M on a so-called suction stroke will cause the check valve 15 in pump piston P to close, so that production fluid in the pump cylinder 2 above the pump piston P will be discharged, as indicated by the arrows, through a suitable number of production ports 18 extending radially through the middle plug 3. At the same time, due to the reduction of pressure in the pump cylinder 2 beneath the piston P during the upstroke, well fluids will unseat the standing valve 17 and pass upwardly therethrough so as to fill the pump cylinder 2 beneath the piston P, so that on the succeeding downstroke of the pump piston P such fluid will transfer through the travelling valve 15 to the pump cylinder above the piston P for ultimate production on the subsequent upstroke of the pump piston P.

In a conventional manner, the assembly shown in Fig. 1 may be lowered into a pump seat (not shown). As is customary in this connection, the fluid-actuated pump assembly may be of the "free pump" type, in accordance with the Dempsey et al. Patent No. 2,653,545, issued September 29, 1953; or as more particularly shown in Dempsey Patent No. 2,631,541, issued March 17, 1953, the fluid-actuated pump assembly of Fig. 1 may be installed in a well by securing the pump to a small string of tubing, commonly called "macaroni tubing," and inserting the pump and the macaroni tubing string in a larger string of well tubing, which is in turn disposed in the well casing for communication with the well fluids to be produced. Other known methods of installation may also be availed of.

Referring more particularly to Fig. 2, it will be noted that the engine piston M comprises a lower body section 19 and an upper body section 20 threadably coupled as at 21 beneath the enlarged central section 7 of the engine piston.

At its upper extremity, the upper body section 20 of the engine piston M is closed as by means of a plug 22, and at the lower end of the engine piston M the middle rod 5 is threaded or otherwise suitably secured to the lower extremity of the piston body section 19 as at 23.

Internally of the upper piston body section 20 is a reduced diameter section 24 which, as best seen in Fig. 3, is provided with a suitable plurality of radially extended ports or openings 11 leading to the engine cylinder space or chamber above the engine piston M, and a plurality of longitudinally extended ports 26 interspersed with the

radial ports 11 and leading through the reduced diameter section 24.

Seating on the shoulder provided at the upper end of the reduced diameter section 24 of the piston body section 20, is a port collar 27, having ports 28 therethrough which establish communication between the longitudinally extended ports 26 just referred to, and a lower main valve chamber 29 which may be considered to include the space directly below the piston head 44.

Abutting with the port collar 27 is a valve cylinder sleeve 30 closely fitting in the engine piston and in sealing engagement at its upper extremity with the top plug 22 of the engine piston, as indicated at 31.

Abutting with the shoulder provided at the lower end of the reduced diameter section 24 of the engine piston body 20, is an annular lower valve seat member 32 which is retained in place by a tubular divider 33, the divider 33 and the seat member 32 being sealed as at 34.

Defined between the divider 33 and the inner periphery of the enlarged central section 7 of the engine piston, is an annular passageway 35 which communicates with the longitudinally extended ports 26 in the reduced section 24 of the piston body. At its lower extremity the divider 33 extends into the lower piston body section 19 and is sealed therewith as at 36.

There is an inwardly directed flange 37 at the lower extremity of the divider 33 which abuts with an outstanding flange 38 on a tubular pilot valve guide 39, the flange 38 in turn abutting against a shoulder 40 formed in the lower piston body section 19. The lower portion of the piston body section 19 is provided with a suitable number of longitudinally extended passages 41 which, as seen in Fig. 4, extend through the body along opposite sides of a slot 42 extending transversely across the body. The passages 41 communicate at their lower end with an annular undercut exhaust chamber 43 which is in communication with the passage 6 through the middle rod 5. At their upper ends, the passages 41 are in communication with an annular space 41a defined between pilot valve means generally indicated at 50 and the divider 33, such communication being effected through a suitable number of ports 41b passing through the flange 37 at the base of the divider 33.

Reciprocably disposed within the valve cylinder 30 is a head 44 of a main valve piston generally designated 45, the latter having an elongated stem 46 threadably or otherwise made integral with the piston head 44 and projecting through the port collar 27 into the lower valve chamber 29 and into the zone lying between the lower valve seat member and the port collar 27.

The port collar 27 is provided with an upper valve seat 47, and on the stem 46 between the valve seats 47 and 32 is a plug valve head 48 which, when seated in the lower valve seat 32 as shown in Fig. 2, enables communication between the lower valve chamber 29 and the radial ports 11 leading to the upper engine cylinder. However, when the plug valve head 48 is engaged with the upper valve seat 47 such communication between the lower valve chamber and the radial ports 11 will be cut off, while communication will be established between such ports 11 and the discharge passage 6 in the middle rod 5, as will more particularly appear hereinafter.

It is significant to note that the inlet ports 10, the annular passageway 35, longitudinally extended ports 26, port collar ports 28 and lower valve chamber 29, constitute a transfer passageway whereby when the valve head 48 is positioned as shown in Fig. 2, power fluid under pressure is transferred from the lower engine cylinder through the engine piston to the upper engine cylinder, so that a downstroke of the engine piston is effected by reason of the fact that the upper end of engine piston M has a larger effective pressure-responsive area than the lower end of the engine piston M, by the cross-sectional area of the middle rod 5 which extends through the middle plug 3.

The lower valve chamber 29 being in constant communication with power fluid under pressure entering the piston M through ports 10, and the lower extremity of the main valve being always subjected to exhaust pressure in the tubular divider 33, it is necessary to apply power fluid under pressure to the upper valve chamber 49 in order to provide a net hydraulic force which is effective to shift the valve head 48 into engagement with the lower valve seat 32 and to maintain such engagement. Alternatively, in order to enable power fluid pressure acting in the lower valve chamber 29 and exhaust pressure acting on the lower extremity of the valve stem 46 to provide a net hydraulic force tending to shift the valve upwardly, it is necessary to establish communication between the upper valve chamber 49 and the exhaust passage 6 through the middle rod 5. Pilot valve means are provided for alternately admitting power fluid to the upper valve chamber 49 and exhausting said upper valve chamber, and in accordance with the invention such pilot valve means is concentrically disposed within the engine piston and extends through the main valve previously described.

In the present embodiment, the pilot valve means is generally denoted at 50 and includes a tubular pilot valve stem which, in this illustrative embodiment, is composed of a lower pilot valve section 51 slidably disposed in a bore 52 extending through the pilot valve guide 39 and extending into the slot 42 in the lower engine piston body section 19. Disposed at the upper extremity of the pilot valve section 51 is a tubular coupling 53, and operatively connected to this coupling at its upper extremity is a pilot valve section 53 which extends into a bore 55 through the main valve piston and stem.

A passageway 56 is provided through the respective pilot valve sections 51, 53 and 54, which is in constant communication with the upper valve chamber 49. The pilot valve section 51 is provided with a lower cross-port 57 and an upper cross-port 58 which are spaced apart a distance less than the length of bore 52. When the pilot valve means 50 is in the position shown in Fig. 2, it will be noted that the lower cross-port 57 communicates with a bore 59 in the lower extremity of the guide 37, which constantly contains power fluid under pressure. Such power fluid enters through the slot 42 in the lower piston body section 19. At the same time, it should be noted that the pilot cross-port 58 is closed, since it is disposed within the confines of the bore 52. Accordingly, power fluid under pressure is free to pass upwardly through the passageway 56 in the pilot valve means and into the upper main valve chamber 49, so as to shift the main valve downwardly into engagement with the lower valve seat 32.

Means are provided for shifting the pilot valve means 50 in opposite directions relative to the engine piston as the engine piston approaches the upward and downward limits of its movement in the engine cylinder. In this connection, as is best seen in Figs. 4 and 5, bottom reversal of the pilot valve means 50 is preferably accomplished by an abutment or saddle 60 which extends transversely through the slot 42 in the lower piston body section 19, and is slidable in said slot. The saddle 60 is connected at its opposite ends as by screws 61 to a collar 62 which is shiftably disposed about the lower extremity of the piston body section and which is engageable with a shoulder 63 (see Fig. 2) in the middle plug 3. Accordingly, as the engine piston moves downwardly and as the lower extremity of the latter moves into a restricted bore 64 in the middle plug 3, the collar 62 will abut with the shoulder 63, causing the saddle 60 to remain stationary as the piston M continues its downward movement and a head 65 on the lower extremity of the pilot valve section 51 abuts with the saddle 60 so as to hold the pilot valve means stationary as the rest of the assembly continues further downward movement.

In order to effect top reversal, the pilot valve means

50 extends upwardly through the top plug 22 of the engine piston M for abutting contact with the upper end 66 of the engine cylinder 1. In the illustrative embodiment, the portion of the pilot valve means which extends through the top plug 22 is a separate element from the pilot valve section 54 and comprises a push rod 67 extending through a bore 68 in the top plug 22 for engagement with the upper end 66 of the engine cylinder, the push rod 67 projecting into the upper valve chamber 49 for engagement with the upper extremity of the pilot valve section 54 as the push rod 67 is forced into the valve chamber upon abutment of the push rod with the top end of the engine cylinder 1.

Preferably as shown in Fig. 2, the top plug 22 is provided with an enlarged bore 69 in which an enlarged central dash-pot piston 70 is shiftably disposed, said piston 70 being formed on the push rod 67 for the purpose of dash-potting movement of the push rod. In addition, the lower end of the push rod 67 is provided with a central passage 71 which communicates through a cross-port 72 with the bore 69.

Operation of embodiment of Fig. 2

Referring to Fig. 6 wherein the fluid-actuated pump is shown in a downstroking condition similar to that shown in Fig. 2, the structural detail of the assembly has been diagrammatically illustrated in order to more clearly illustrate the path of fluid flow through the various ports and passages in the operation of the engine.

In Fig. 6 the main valve head 48 is engaged with the lowermost valve seat, so that power fluid entering the engine cylinder through ports 9 will pass from the lower engine cylinder through inlet ports 10, annular passageway 35, passages 26 and ports 28, into the lower valve chamber, from whence it will pass through radial ports 11 into the upper engine cylinder, thus providing a net hydraulic force acting on the upper end of the engine piston which will correspondingly effect a downstroke of the pump piston P to close off check valve 17 while check valve 15 opens to permit production fluid to pass upwardly therethrough into the upper pump cylinder. At the same time, power fluid passes from the lower engine cylinder through slot 42 and into the passage 56 in the pilot valve means 50 through the pilot valve cross-port 57. Accordingly, power fluid is admitted to the upper valve chamber 49 to provide a net hydraulic force holding the valve head 48 on the lowermost seat.

For a reason which will hereinafter be more particularly described, the push rod 67 is maintained as shown in Fig. 6, projecting to its fullest extent from the upper end of the engine piston.

The annular space 41a defined between the divider 33 and the pilot valve means 50 is, of course, subjected to exhaust pressure through ports 41b and passages 41 leading from chamber 43 at the base of the piston, which chamber is in communication with the exhaust opening 6 through the middle rod 5. As will be evident, the exhaust pressure in the chamber 41a is principally the hydrostatic head of production fluid in a conduit leading to the earth's surface.

Referring now to Fig. 6a, the engine piston is shown at the bottom of its downstroke where the bottom reversal of the valve means takes place. Downward movement of the engine piston M has brought collar 62 of the pilot valve abutment means into engagement with the stop shoulder 63 as the lower extremity of the engine piston entered the restricted bore 64. Further downward movement has brought the lower extremity of the pilot valve means 50 into engagement with the saddle 60, thus arresting further downward movement of the pilot valve means along with the engine piston. As a result, the pilot valve means has moved within the bore 52 of the pilot valve guide and in the bore 55 through the main valve, so that the pilot valve cross-port 57 has been closed off in the bore 52, while the cross-port 58 now is open to communication with exhaust fluid in chamber 41a.

Accordingly, the upper valve chamber 49 has been exhausted through the pilot valve passage 56. In addition, power fluid pressure in the upper engine cylinder will be now acting upon the outer end area of the push rod 67, while the inner end of the push rod 67 and the annular piston 70 are exposed to exhaust pressure, with the result that there will be a net hydraulic force to shift the push rod 67 inwardly. Such inward movement of the push rod, however, will be dampened by the dash-pot effect of the piston 70 in the bore 69 to prevent slamming of the push rod 67 into the upper extremity of the pilot valve stem.

Due to the exhausting of the upper valve chamber 49, the effect of power fluid in the lower valve chamber 29 acting upon the downwardly facing area of the main valve piston head 44 will provide a net hydraulic force acting upwardly on the main valve to lift the latter and shift the same to the position shown in Fig. 7 where an upstroke condition exists.

As shown in Fig. 7, the main valve head 48, as a result of the aforementioned net upwardly-acting hydraulic force acting on the main valve piston head 44 has been shifted upwardly into engagement with the top seat 47, so that the fluid pressure transfer passage from inlet ports 10 to ports 11 leading to the upper engine cylinder has been closed off, and now the ports 11 are in open communication with the annular chamber 14a which is in constant communication with the exhaust passage 6 through the middle rod 5.

It should be noted here that power fluid which is constantly acting on the lower extremity of the pilot valve means 50, is now effective to provide a hydraulic force holding the pilot valve means 50 in the upward position as shown in Fig. 7.

During the upstroke of the fluid-actuated pump production fluid will pass upwardly through the standing check valve 17 into the pump chamber beneath the pump piston P, while the travelling check valve 15 will be closed off and the engine exhaust fluid as well as production fluid in the pump chamber above the pump piston P will be discharged through ports 18 for conduction to the earth's surface.

Continued upward movement of the engine piston will bring the push rod 67 into engagement with the upper end 66 of the engine cylinder 1 to effect a shift of the valve means at the top reversal as particularly illustrated in Fig. 7a. Top reversal of the valve means is shown in Fig. 7a at a stage just prior to the existence of a down-stroking condition, namely, substantially at the mid-point in the pressure-responsive shift of the main valve.

It will be noted that upward movement of the engine piston has brought the push rod 67 into engagement with the upper end of the engine cylinder 1, so that the lower extremity of the push rod 67 contacting the upper end of the pilot valve stem has arrested upward movement of the pilot valve means while the engine piston and main valve have continued to travel upwardly. Thus, pilot valve cross-port 57 is open to communication with power fluid entering through cross-slot 42, while upper pilot valve cross-port 58 is now closed off in the bore 52 of the pilot valve guide.

Accordingly, power fluid now passes through the pilot valve passage 56 into the main valve chamber 49 to effect downward movement of the main valve piston, unseating the valve head 48 from the upper valve seat and moving the valve head towards the lower seat.

As the valve head reverses the ports 11, so that they no longer communicate with the exhaust chamber 41a but instead progressively communicate with the lower valve chamber 29, power fluid will transfer through the ports 11 to the upper engine cylinder to again act upon the larger end area of the engine piston to drive the same downwardly.

During the course of this top reversal, downward movement of the engine piston may commence at a time when

the pressure in the upper engine cylinder is less than the pressure in the upper valve chamber, since the upper valve chamber 49 must be subjected to power fluid pressure to shift the main valve before the engine piston will reverse. Accordingly, as the engine piston moves away from the upper end of the engine cylinder pressure in the upper valve chamber will force the push rod 67 outwardly of the upper valve chamber, but such outward movement of the push rod is dampened by the dash-pot effect of the annular piston 70 in the bore 69 of the upper piston head.

The ratio of the several areas of the main valve are such that under normal pump operation the degree of pressure in valve chamber 49 capable of moving said main valve to its lower seat is less than the pressure required in the upper engine cylinder cavity to institute engine piston movement. However, in immediate sequence said cavity 49 will experience total motive pressure as noted due to "saturation," whereas the upper engine cylinder cavity will experience less than static motive pressure due to engine piston speed. As a consequence of the mechanical movement of the pilot valve assembly at either end of a stroke, instituting fluid flow to or from the upper valve chamber 49, the several areas of each the main valve and pilot valve assembly receive proper motive fluid pressure bias to enforce and/or continue the movement of the pilot valve in the direction instituted and to force both members to their limit of travel.

Dash-potting of the outward movement of the push rod 67, moreover, is particularly desirable in those instances where the pump is operating in a gassy well and during the upstroke the lower pump chamber may be partially filled with gas, under which circumstances, as the engine valving is reversed the engine piston may commence its downward movement prematurely before pressure has effectively transferred from the lower engine cylinder to the upper engine cylinder.

The just-described cycling of the engine will continue so long as power fluid is supplied to the engine through the inlet port 9.

From the foregoing description it is apparent that the mode of operation of the fluid-actuated engine is such that the main valve is held upwardly in the engine piston during upstroke of the latter, and is held downwardly during downstroke thereof.

Figures 8 and 9

In Figs. 8 and 9 there is shown an embodiment of the invention wherein the main valve shifts in a direction opposite to the direction of travel of the engine piston.

Furthermore, in the embodiment first described the pilot valve porting is alternately opened and closed as a result of movement of the pilot valve cross-ports 57 and 58 alternately into and out of the bore 52 in the pilot valve guide. In the embodiment of Figs. 8 and 9, however, as will presently appear, the pilot valve cross-porting is adapted to effect reversal of the main valve as a result of movement of the cross-porting alternately into and out of a bore in the main valve itself.

In the essential respects the engine cylinder and engine piston of Figs. 8 and 9 is similar to that previously described, and accordingly reference characters in the 100 series are employed where applicable. Moreover, the engine cylinder is adapted to be connected in axial alignment to a pump cylinder as in the previously described embodiment.

Accordingly, referring to Fig. 8 it will be noted that the engine cylinder 101 is threaded into the middle plug 103 through which extends the middle rod 105 having exhaust passage 106 therethrough. Reciprocally disposed in the engine cylinder is the motor piston M which is composed of lower piston body section 119 and upper piston body section 120 threadedly interconnected as at

121. Disposed in the engine piston is a valve cylinder 130 which abuts with the port collar 127 providing the upper valve seat 147.

Abutting with the reduced diameter central section 124 is a tubular divider 133 having a lower valve seat 132 formed thereon. The lower valve chamber 129 is constantly in communication with the exhaust passage 106 through the middle rod 105, through port collar ports 128, longitudinally extended passages 126 in the reduced diameter section 124, annular space 135 between the divider 133 and the inner wall of the lower piston body section 119, passages 141 through the lower extremity of the piston section 119 and undercut chamber 143 at the lower extremity of the latter.

With the engine in a downstroking condition as shown in Fig. 8, fluid entering through middle plug port 109 will enter through cross-slot 142 into the tubular divider 133, and will pass upwardly around the lower extremity of main valve head 148, through radial ports 111, and thence into the upper end of the engine cylinder where a net hydraulic force urging the engine piston downwardly is provided.

In this embodiment the valve head 148 is removable from the main valve stem 146 and is threaded thereto as at 146a. Moreover, in this embodiment the pilot valve means 150 comprises an upper push rod 167 shiftable disposed in a bore 168 of top plug 122 of the piston, a central pilot valve section 154 extending through the bore 155 in the main valve stem, and a lower push rod 167a slidable in the tubular divider 133.

Pilot valve cross-port 157 communicates with the passageway 156 extending through the pilot valve section 154. As shown in Fig. 8, this pilot valve cross-port 157 is sealed in the bore of the main valve, so that power fluid in the passageway 156 of the pilot valve is precluded from passing into the upper valve chamber, i.e. upwardly through the valve piston head 144 of main valve piston 145.

It will be noted that the valve stem 146 is provided with a chamber 144a in which is reciprocally disposed a pilot valve head 144b, having a passage 144c extending axially therethrough and communicating with the chamber 144a through angularly disposed ports 144d. Pilot valve porting 158 is provided in the piston head 144 in this embodiment by means of an annular chamber 158a in a bore 158b through the valve piston head, the porting 158 communicating with the chamber 158a and with the lower valve chamber 129 when the valve means is conditioned for effecting a downstroking of the engine, and the upper valve chamber between piston head 144 and top plug 122 also being opened to exhaust pressure through an annular clearance 158c formed in a piston head 170 on upper push rod 167 and the bore 158b through the piston head 144.

With the valve means in the condition shown in Fig. 8, it will be noted that power fluid under pressure acts upon the cross-sectional end area of the valve head 148 and the main valve stem 146 to provide a net force in an upward direction to hold the valve head 148 on the upper seat 147, inasmuch as the annular cross-sectional area of the piston head 144 is exposed to exhaust pressure in the valve chamber 129 beneath the piston head 144 as well as in the upper valve chamber.

Further, it should be noted that the push rod 167 is of a diameter slightly greater than the diameter of the pilot valve member 154 which is exposed to power fluid pressure in the divider 133. Accordingly, there is provided a net hydraulic force acting on the upper end of push rod 167 which is effective to hold the pilot valve member 154 in the position shown in Fig. 8, with the head 154 thereon engaged at the base of the bore 158b.

It will be understood that the just-mentioned hydraulic force becomes available at the upper reversal of the engine piston so that the pilot valve means is effectively maintained by power fluid pressure in a proper condition

for holding the main valve head 148 in engagement with the upper seat 147.

Referring to Fig. 9, the engine is shown at the bottom reversal with the main valve in a position for enabling the exhaust of fluid from the upper engine cylinder. It will be noted that the lower end of the pilot valve member 154 is subjected to power fluid pressure in the divider 133, and also chamber 144a in the main valve stem 146 is open to power fluid pressure passing upwardly through central passageway 156 and through pilot valve cross-ports 157, from which point power fluid passes upwardly through ports 144d and central passage 144c in the pilot head 144b into the upper valve chamber between the main valve piston 144 and top plug 122.

Under these pressure conditions the piston head 170 on the upper push rod 167 will be fully seated in dash-pot bore 169, so as to limit further upward movement of the pilot valve means 150 which will be held in such position by reason of a net hydraulic force being exerted in an upper direction at the lower extremity of the pilot valve member 154. Thus the pilot valve means is also shifted by hydraulic pressure at the lower reversal, though it is initially unseated mechanically by engagement of the lower push rod 167a with the saddle 160 extending through cross-slot 142 as is shown in Fig. 9.

As in the embodiment previously described, the saddle 160 is suitably secured to an abutment collar 162 slidable about the lower extremity of the piston body section 119 and engageable with a stop shoulder 163 as the lower extremity of the piston body section 119 moves into the dash-pot chamber 164. The lower push rod 167a, however, is slidably disposed within the tubular divider 133 and is centered therein as by a suitable plurality of radially projecting ribs 167b. At its upper extremity the push rod 167a is longitudinally ported as at 167c and transversely cross-ported at 167d, so as to enable communication of power fluid into the passageway 156 through the pilot valve member 154.

A spring 167e is interposed between a shoulder 167f internally of the divider 133 and the ribs 167, so as to normally bias the push rod 167a downwardly, this spring being compressed during mechanical shifting of the pilot valve means at the bottom reversal of the engine as shown in Fig. 9.

It should be noted in respect to the embodiment of Figs. 8 and 9, that since the main valve head 148 and the engine piston head move in opposite directions upon reversal of the direction of travel of the engine at the end of its upstroke and downstroke, high velocity flow through radial ports 111 is minimized.

In the embodiment illustrated by Fig. 8, the engine piston is biased for downstroke movement. The pilot valve assembly in secondary movement was forced to the position as shown by motivating pressure transferring into the upper engine cylinder cavity reacting against the area of bore 168 in greater force than that of motive pressure acting against the area of bore 155; i.e., 168 is greater than 155.

Fig. 9 shows parts positioned for upstroke and it is obvious that the secondary pilot valve movement attended a differential pressure development between inlet slot 142 and the upper engine cylinder cavity before the pilot valve reached the position as illustrated.

It is further obvious that the area relationship between bore 168 and bore 155 will indicate the percentage of pressure variable that must exist between motive fluid pressure and the pressure existing in the upper engine cylinder cavity to produce, nullify, or reverse the needed bias for proper pump function.

Figs. 10 and 11

In Figs. 10 and 11 there is shown a further modified construction wherein, as in the case of the valve means of Figs. 8 and 9, the main valve piston and the engine piston travel in opposite directions at the top and bottom

reversals, but wherein the pilot valve porting, instead of being located within the main valve piston is slidable in the pilot valve guide, similar to the embodiment of Figs. 1 through 7. However, the pilot valve guide extends into the exhaust fluid passage.

Again, in Figs. 10 and 11 the essential details of the engine piston and the valve means are the same as those previously described and accordingly reference numerals in the 200 series are employed.

Referring to Fig. 10, the engine piston M is disposed in the engine cylinder 201, as in the previously described embodiments, includes a lower engine piston body section 219 and upper piston body section 220, with a reduced internal central section 224 through which power fluid transfer ports 211 extend and in which the main valve head 248 is shiftable between upper seat 247 and lower seat 232.

The pilot valve means 250 is adapted to effect reversal of the pressure conditions applicable to the main valve piston 245 so as to alternately admit power fluid to the upper valve chamber between the piston head 244 and top plug 222, and to exhaust such power fluid through the longitudinally extended passageway 256 extending through the pilot valve means 250.

Lower valve chamber 229 is constantly in communication with the exhaust passage 206 through middle rod 205, via port collar ports 228, longitudinally extended passages 226, annular space 235 between the divider 233 and the inside wall of the engine piston, and through longitudinally extended passageways 241 extending through the lower piston body section 219 into exhaust chamber 243.

With the valve means conditioned as shown in Fig. 10, power fluid is free to enter the tubular divider 233 through cross-slot 242 in which the saddle 260 is disposed. Such power fluid is accordingly free to pass through the fluid pressure transfer passage 211 into the upper engine cylinder to effect downstroke of the engine piston M.

It should be noted that in this form the pilot valve guide designated 239 is elongated and projects as at 239a through a bore 239b in the engine piston body section 219, into the annular discharge chamber 243. Cross-ports 239c establish communication between the chamber 243 and an annular chamber 239d within the valve guide 239, and when the engine is downstroking, as shown in Fig. 10, pilot valve cross-ports 258 communicate with the annular chamber 239d, so that the upper valve chamber between main valve piston head 244 and top plug 222 is exhausted through the central passageway 256 through the pilot valve means.

At the same time it should be noted that pilot valve cross-port 257 is sealed off in bore 252 of the valve guide 239. The lower pilot valve stem 251 containing the cross-ports 257 and 258 extends through an enlarged bore 260a through the saddle 260, and is provided with an outstanding flange 251a engageable with the saddle 260 to arrest downward movement of the pilot valve means at the lower end of the downstroke movement of the engine piston.

In this embodiment, the saddle 260 is connected to abutment collar 262 by means of a suitable number of diametrically spaced connecting arms 262a, the arms 262 being pinned as at 262b to the outer extremities of the saddle 260. Assembly of the pin 262b with the saddle 260 and connecting arms 262a is effected by passage of the pin through a chordal slot 262c in the lower engine piston body section 219 prior to the installation of the pilot valve means in the assembly. Following complete assembly of the engine, upward movement of the saddle 260 is limited by the flange 251a so that the pin 262b cannot reach the slot 262c.

As shown in Fig. 10, the flange 251a on the pilot valve member 251 is in engagement with the saddle 260 so that as the lower extremity of the piston body section 219 moves into the dash-potting bore 264 the abutment collar

262 will contact shoulder 263; thus limiting further downward movement of the pilot valve means as the piston M moves further downwardly. Therefore, the pilot valve crossport 258 will be moved into the valve guide bore 252 while crossport 257 is opened to power fluid pressure in the bore 260a through the saddle 260, as shown in Fig. 11. At this time, power fluid under pressure will pass upwardly through the passageway 256 through the pilot valve means into the upper valve chamber between piston head 244 and top plug 222, so as to effect reversal of the main valve and consequent engagement of the valve head 248 with the lower seat 232, thereby opening the upper engine cylinder to exhaust through the radial ports 211, lower valve chamber 229, port collar ports 228, longitudinally extended passages 226, annulus 235 and elongated passageways 241, into annular exhaust chamber 243.

It will be noted that the pilot valve means as shown in Fig. 11 is virtually hydraulically balanced. However, it is desirable that at the end of the upstroke the pilot valve means be shifted downwardly hydraulically. This is accomplished by reason of the restriction to exhaust flow through the passage 256 in the pilot valve means from the upper valve chamber, upon closure of pilot valve crossport 257 to power fluid pressure, and opening of crossport 258 to exhaust pressure in annular space 239d in the valve guide 239, since the first stage of exhaust will be in the lower extremity of the bore 252 in the valve guide 239, and power fluid pressure, upon top reversal of the pilot valve, immediately commences to reverse the main valve seating relationship, thus affording a net hydraulic force acting upon the upper extremity of the upper pilot valve member 254 while said main valve is moving upwardly. If desired, however, the pilot valve means 250 may be so proportioned as to provide a pressure responsive area for shifting the pilot valve downwardly independently of movement of the main valve.

At the bottom reversal of course, when the upper engine cylinder is exhausted as aforementioned and the pilot valve crossport 257 communicates with power fluid in the bore 260a of saddle 260, power fluid passes downwardly through pilot valve passageway 256 into the chamber formed at the lower extremity of the valve guide 239 and acts upon the lower extremity of the pilot valve stem 251 to shift the pilot valve means upwardly.

Accordingly, hydraulic forces are effective at both the top and bottom reversals of the valve means to effect a complete reversal.

Figs. 12 and 13

Referring now to Figs. 12 and 13, there is illustrated a further embodiment of the invention incorporating pilot valve porting within the pilot valve guide as shown in Figs. 10 and 11 in combination with a main valve construction corresponding generally to that shown in Figs. 8 and 9.

The general construction of the assembly of Figs. 12 and 13 is similar to that previously described, and accordingly reference numerals in the 300 series are employed, wherein it will be noted that 301 designates the motor cylinder in which the motor piston M is reciprocable. The motor piston again in this form comprises the lower and upper body sections 319 and 320 respectively.

In the upper piston body section 320 is a valve cylinder 330 in which the main valve piston 345 is reciprocable, said main valve piston having a stem 346 on which is preferably removably secured a valve head 348 alternately engageable with upper and lower valve seats 347 and 332 respectively, during the downstroke and upstroke, respectively, of the engine piston.

The lower valve chamber 329 communicates through port collar ports 328 with longitudinally extended pas-

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sages 326 leading into annular space 335 lying between the tubular divider 333 and the inner wall of the piston body, the annulus 335 communicating through longitudinally extended passages 341 with annular exhaust space 343 at the base of the engine piston, and the chamber 343 communicating with passage 306 through middle rod 305.

Reciprocably extending through a bore 368 through the top plug 322 of the engine piston, is the push rod 367, having dash-pot piston 370 thereon. The push rod 367 is adapted to engage a shuttle 344b which is reciprocable in the bore 358b formed in the main valve piston head 344.

Shuttle 344b is provided with a passage 344c there-through and end passages 344d for establishing communication between the passage 344c and the chamber formed at the base of the bore 358b, so that when the engine is in the downstroking condition as shown in Fig. 12, fluid is exhausted into the lower valve chamber 329, through angularly disposed passages 390 communicating with an annulus 391 within the main valve piston head 344.

Disposed beneath the shuttle 344b and shiftably disposed in the main valve stem 346 is the upper section 354 of pilot valve means 350. It should be understood that the shuttle 344b may if desired be made integral with pilot valve section 354. In this embodiment of the invention the pilot valve portion 354 is integral with the lower pilot valve section 351, being interconnected by an enlarged central section 353. However, the pilot valve passageway 356 is in constant communication with power fluid under pressure through crossport 393 at the juncture of the upper and middle pilot valve sections 354 and 353 respectively.

At its upper extremity the pilot valve passageway 356 is blocked off as by a plug 394, there being a crossport 395 through the upper pilot valve section 354 which is alternately adapted to establish communication between the chamber beneath shuttle 344b in bore 358b and to be closed off in the bore 355 through the main valve stem 346. The engine is in a downstroke condition as shown in Fig. 12, and accordingly the crossport 395 is closed, while the shuttle is in a position opening the upper valve chamber between the main valve piston 344 and the top plug 322 to exhaust as aforementioned.

It will be noted that power fluid is effective across the cross-sectional area of push rod 367 in the upper engine cylinder to hold the pilot valve means downwardly during downstroking of the engine, while at its lower extremity the pilot valve means extends into the pilot valve guide 339, having an annular chamber 339d in constant communication through transverse ports 339c with the exhaust chamber 343. In addition, there is an axial passage 395 in the lower end of the pilot valve member 351 communicating with the chamber 339d through crossports 396, so that the chamber 397 at the bottom of the bore 352 in the valve guide 339 is open to exhaust pressure.

As the engine piston approaches the lower limit of its downstroke movement the central section 353 of the pilot valve means 350 will engage the saddle 360 which, as will now be apparent, will be limited to the extent of its downward movement upon engagement of the collar 362 with abutment shoulder 363 at the upper end of dash-pot cavity 264 so as to effect relative movement between the pilot valve means and the downwardly travelling engine piston and main valve, whereupon the pilot valve porting will be reversed, as shown in Fig. 13.

As shown in this latter view, there is a crossport 398 extending through the lower section 351 of the pilot valve means which communicates with the central passageway 395 therein, so that power fluid under pressure is admitted into the chamber 397 at the base of the bore 352 in guide 339. In addition, crossport 395 at the upper end of the upper pilot valve section 354 is caused to communicate with the chamber beneath the shuttle 344b,

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so that power fluid under pressure passes through cross-slot 342 in the engine piston upwardly through divider 333 so as to act upon the lower end of the main valve stem 346, while power fluid passes upwardly through pilot valve passage 356 and through crossport 395, and thence upwardly through passage 344c in the shuttle 344b, into the upper valve chamber between the main valve piston head 344 and the top plug 322.

Accordingly, the main valve head 348 will be held on the lower seat 332 while the pilot valve means is maintained in an upward position as shown in Fig. 13 due to the net hydraulic force applied to the lower extremity of the pilot valve means in the chamber 397, it being noted that the pilot valve means is hydraulically balanced except for the end thereof in chamber 397 and the upper extremity of the push rod 367 which, in the upstroke condition, is exposed to exhaust pressure in the upper engine chamber.

Thus during both the upstroke and downstroke of the engine piston, pilot valve action is mechanically initiated followed by hydraulic operation by selectively proportioning the cross-sectional areas of the pilot valve components.

While the various details of the several embodiments of the invention have been herein shown and described, changes and alterations may be resorted to without departing from the spirit of the invention as defined in the appended claims. Particularly, cross-sectional relationships may be varied so as to effect the desired variations in hydraulic response of the engine piston, main valve piston and pilot valve means, as may be required for operation of the pump in wells wherein different operating conditions obtain.

In each of the several embodiments herein disclosed, the primary movement of the pilot valve assembly is mechanically shifted into reversing position by the net hydraulic bias of the engine piston as it approaches its limit of travel at either end of a total stroke. The manner in which this primary movement of the pilot valve is instrumented represents one phase of valve improvement. For many inherent reasons it is obvious that additional latitude for pilot valve movement beyond the limit of hydraulic bias of the engine piston must be provided the pilot valve. This over-ride or secondary movement of the pilot valve is enforced by a net hydraulic force reacting coincidentally and/or separately upon both the main valve and pilot valve as hereinbefore stated.

During normal pump operation, the engine piston is enforced in downstroke movement by a near total motive fluid pressure in the upper engine cylinder cavity and in upstroke movement by a near exhaust fluid pressure in said engine cylinder cavity. Under conditions of total cavitation in the lower pump (suction) chamber (critically abnormal pumping conditions) the engine piston cycle will be enforced with the above pressure conditions substantially reversed in said upper engine cavity. This condition rapidly diminishes as engine piston moves upward from its position of lower limit turn-about. In like manner down-stroke movement of the engine piston when under total and/or partial pump chamber cavitation (near normal pumping condition) will be enforced by empounded exhaust fluid pressure reacting against the top face of the pump piston plus a total reversal of normal pressure requirement in the upper engine cylinder cavity. As engine piston moves away from its upper limit turn-about power demand created by compression in lower pump piston cavity induces requirement in the upper engine piston chamber to increase towards normal pressure value.

A "near-normal" pumping condition exists when the pump piston in downward movement encounters and displaces liquid by the time that pilot valve means have been mechanically shifted to reversing position. It is evident that the ensuing secondary movement of said valve will be enforced under normal upper engine cylinder pressure

conditions. This "near-normal" pumping condition must be considered as standard for a majority of pump installations because the operator will consistently operate his equipment beyond well capacity. For this reason the valve means herein referred to, with the exceptions of Fig. 8 and Fig. 9 (as previously noted) are designed with ample latitude given the top turn-about.

The main valve and parts 51 and 54 of the pilot valve are so proportioned that the thrust of motive fluid pressure plus the thrust of exhaust fluid pressure reacting in one direction are balanced by an increasing or decreasing pressure in the upper valve cavity 49. It has been found that when the apparent "balancing pressure" of cavity 49 assumes a pressure equal to the exhaust fluid pressure plus approximately one-half the differential between the motive and exhaust fluid pressures, both members of the valve means proceed in near simultaneous accord to a completely reversed position. This action is easily apparent with reference top reversal as indicated in Fig. 7a.

Under conditions of complete pump chamber cavitation, the piston unit is inhibited from instantaneous reverse movement (re. Fig. 6a) by the kinetic energy developed in retrograde fluid flow down the production tubing plus the inertia of instituting the flow of said liquid movement up said tubing. This momentary hesitation allows complete liquid exhaust from upper valve chamber 49 as said exhaust relates to valve means movement. The downward bias of the pilot valve assembly (i.e., 51 and 54, plus 67) is held by abutment member 60 during the interval that motive fluid pressure commands the top face of 67 (upper valve chamber) plus the exhausting pressure of 49 induced by the upward thrust of main valve until said main valve comes to rest against its seat. The proportionate values of parts 51, 54 and 67 are such that its constant upward fluid pressure bias overcomes the downward bias of the total motive pressure intensity residing in the upper engine cylinder cavity plus a safe degree of residue pressure exhausting from cavity 49 at the instant the main valve reaches at rest position before the piston unit receives sufficient bias to move.

I claim:

1. In a fluid-actuated deep well pump comprising the combination of a double-acting motor including a cylinder and a motor piston reciprocable therein, said piston having oppositely directed faces of different areas, the smaller of said faces being adapted to be in continuous open communication with a source of operating fluid; a pump including a cylinder and a pump piston reciprocable therein; a piston rod interconnecting said pump and motor pistons, said rod having a fluid passageway extending axially therethrough and communicating at one end with said pump cylinder; and valve means carried by said motor piston and operable to provide communication between the larger of said motor piston faces and alternately, said source of operating fluid and said fluid passageway in said piston rod; the improvement wherein said valve means includes fluid pressure operated main valve means concentrically disposed in said motor piston, pilot valve means concentrically disposed in said main valve means and reciprocable therein for controlling the fluid pressure responsive operation of said main valve means to shift said main valve means, and abutment means within said motor cylinder at opposite ends of said motor cylinder for shifting said pilot valve means.

2. A fluid-actuated deepwell pump as defined in claim 1, wherein said abutment means includes a member shiftably carried by said motor piston and engageable with the end of said motor cylinder.

3. A fluid-actuated deep well pump as defined in claim 1, wherein said abutment means at one end of the motor piston includes a push rod reciprocably extending through said end of the motor piston for engagement with the adjacent end of the motor cylinder.

4. A fluid-actuated deep well pump as defined in claim

3, including means for dashpotting reciprocation of said push rod.

5. A fluid-actuated deep well pump as defined in claim 1, wherein said abutment means at one end of the motor piston includes a saddle extending transversely through said motor piston, and a member slidably mounted on said motor piston and connected to said saddle, said motor cylinder end adjacent to said slidable member having a shoulder engageable by said slidable member.

6. In a fluid-actuated deep well pump comprising the combination of a double-acting motor including a cylinder and motor piston reciprocable therein, said piston having oppositely directed faces of different areas, the smaller of said faces being adapted to be in continuous open communication with a source of operating fluid; a pump including a cylinder and a pump piston reciprocable therein; a piston rod interconnecting said pump and motor pistons, said rod having a fluid passageway extending axially therethrough and communicating at one end with said pump cylinder; and valve means carried by said motor piston and operable to provide communication between the larger of said motor piston faces and alternately, said source of operating fluid and said fluid passageway in said piston rod; the improvement wherein said valve means includes fluid pressure operated main valve means concentrically disposed in said motor piston, pilot valve means concentrically disposed in said main valve means and reciprocable therein for controlling the fluid pressure responsive operation of said main valve means to shift said main valve means, abutment means at opposite ends of said motor cylinder for shifting said pilot valve means, and means for dashpotting movement of said pilot valve means.

7. In a fluid-actuated deep well pump comprising the combination of a double-acting motor including a cylinder and a motor piston reciprocable therein, said piston having oppositely directed faces of different areas, the smaller of said faces being adapted to be in continuous open communication with a source of operating fluid; a pump including a cylinder and a pump piston reciprocable therein; a piston rod interconnecting said pump and motor pistons, said rod having a fluid passageway extending axially therethrough and communicating at one end with said pump cylinder; and valve means carried by said motor piston and operable to provide communication between the larger of said motor piston faces and alternately, said source of operating fluid and said fluid passageway in said piston rod; the improvement wherein said valve means includes fluid pressure operated main valve means concentrically disposed in said motor piston, pilot valve means concentrically disposed in said main valve means and reciprocable therein for controlling the fluid pressure responsive operation of said main valve means to shift said main valve means and extending through said motor piston at one end for engagement with the end of said motor cylinder to effect movement of said pilot valve means in one direction, and abutment means engageable with said pilot valve means at the other end of said motor piston for shifting said pilot valve means in the other direction.

8. In a fluid-actuated deep well pump comprising the combination of a double-acting motor including a cylinder and a motor piston reciprocable therein, said piston having oppositely directed faces of different area, the smaller of said faces being adapted to be in continuous open communication with a source of operating fluid; a pump including a cylinder and a pump piston reciprocable therein; a piston rod interconnecting said pump and motor pistons, said rod having a fluid exhaust passageway extending axially therethrough and communicating at one end with said pump cylinder; and valve means carried by said motor piston and operable to provide communication between the larger of said motor piston faces and alternately, said source of operating fluid and said fluid passageway in said piston rod; the improve-

ment wherein said valve means includes fluid pressure operated main valve means concentrically disposed in said motor piston, pilot valve means concentrically disposed in said main valve means and reciprocable therein for controlling the fluid pressure responsive operation of said main valve means to shift said main valve means, abutment means at opposite ends of said motor cylinder for shifting said pilot valve means, said main valve means including a valve piston having differential end areas, and said pilot valve means having ports alternately establishing communication between the larger of said main valve piston end areas and said source of fluid under pressure and said passageway in said piston rod upon movement of said pilot valve means in opposite directions.

9. A fluid-actuated deep well pump as defined in claim 8, wherein said pilot valve means is provided with a passage therethrough in constant communication with the larger end area of said main valve piston and with said ports.

10. A fluid-actuated deep well pump as defined in claim 8, wherein said pilot valve means includes a stem having a passage extending longitudinally thereof and communicating with said ports, said motor piston having a bore in which said stem is slidably disposed with said stem exposed to said power fluid at one end of the bore and to the pressure of fluid in said exhaust passageway at the other end of said bore, said ports being located in relation along said stem so that said ports are exposed at one end of the bore upon movement of said stem in one direction and at the other end of said bore upon movement of said stem in the other direction.

11. A fluid-actuated deep well pump as defined in claim 8, wherein said pilot valve means includes a stem having a passage extending longitudinally thereof and communicating with said ports, said motor piston having a bore closed at one end in which one end of said stem is slidably disposed, said bore being in communication with said exhaust passageway, and said ports being spaced along said stem so as to alternately establish communication through said ports between said exhaust passageway and said passage in said stem and between said passage in said stem and said source of operating fluid upon movement of said stem in opposite directions.

12. In a fluid-pressure operated motor pump comprising an engine cylinder and a pump cylinder below said engine cylinder, an engine piston reciprocable in said engine cylinder, a pump piston reciprocable in said pump cylinder, a hollow rod connecting said engine and pump pistons, said engine cylinder having a power fluid inlet port communicating with the lower end of the engine cylinder, passageways for conducting fluid from the lower end of the engine cylinder to the upper end thereof and for exhausting fluid from the upper end of the engine cylinder into said hollow rod, and valve means for alternately permitting and preventing the flow of fluid into and the exhaust of fluid from the upper end of said engine cylinder, that improvement wherein said valve means includes a fluid pressure operated main valve concentrically disposed in said engine piston, pilot valve means extending coaxially through said main valve for reversing the effect of fluid pressure on said main valve upon reciprocation of said pilot valve means, and means wholly within said engine cylinder for shifting said pilot valve in opposite directions when said engine piston approaches the end of its movement in opposite directions in said engine cylinder.

13. A fluid operated reciprocating engine comprising a cylinder, an engine piston reciprocable in said cylinder, valve means to control the application of differential motive fluid pressures to said cylinder at opposite ends of the engine piston, said valve means including a main valve piston, said engine piston having a valve chamber extending axially therein in which said main valve piston is disposed, pilot valve means extending coaxially through said main valve piston for controlling the application of

motive fluid pressure to said valve chamber at opposite ends of said main valve piston to effect reciprocation of said main valve piston, and means wholly within said cylinder for effecting reciprocation of said pilot valve means as said engine piston approaches the end of its movement in said cylinder in opposite directions.

14. A fluid operated reciprocating engine as defined in claim 13, wherein said pilot valve means projects through one end of said engine piston for abutting engagement with the adjacent end of said cylinder upon movement of said engine piston in one direction, and including relatively stationary means engageable with said pilot valve means upon movement of the engine piston in the opposite direction.

15. A fluid operated reciprocating engine as defined in claim 13, wherein said pilot valve means includes fluid pressure responsive areas subjected to fluid pressure for biasing said pilot valve means in opposite directions.

16. A fluid operated reciprocating engine as defined in claim 13, wherein said pilot valve means includes fluid pressure responsive areas subjected to fluid pressure for biasing said pilot valve means in one direction.

17. In a fluid operated reciprocating engine comprising a cylinder, an engine piston reciprocable in said cylinder and having differential end areas whereby operating fluid under pressure admitted to said cylinder at opposite ends of said piston and alternately exhausted from said cylinder at the larger end of said piston will effect reciprocation of the piston, the improvement comprising valve means to control the flow of power fluid to and exhaust from said cylinder at the larger end of the piston, said valve means including a differential end area main valve piston, said engine piston having a valve chamber extending axially therein in which said main valve piston is disposed, pilot valve means extending coaxially through said main valve piston for alternately admitting power fluid to said valve chamber at the larger end of said main valve piston and exhausting said valve chamber upon reciprocation of said pilot valve means, and means wholly within said cylinder for effecting reciprocation of said pilot valve means as said engine piston approaches the end of its movement in said cylinder in opposite directions.

18. A fluid operated reciprocating engine as defined in claim 17, wherein said pilot valve means includes a stem having a longitudinally extended passage therethrough and axially spaced transverse ports communicating with said passage, said engine and main valve pistons having bores in which said stem is shiftably disposed, said transverse ports being spaced along said stem so that said passage in said stem alternately communicates through said passages with operating fluid and with exhaust and said ports are alternately sealed off in one of said bores upon reciprocation of said stem, and said passage in said stem communicating with said main valve chamber at one side of the main valve piston upon movement of the pilot valve means in one direction.

19. A fluid pressure operated engine for reciprocating well pumps, comprising an engine cylinder, a differential end area piston shiftably disposed in said cylinder, said cylinder having an inlet port for the admission of power fluid, said piston having a valve chamber therein, a pressure transfer passageway for establishing communication between said valve chamber and said cylinder, and an exhaust passage communicating with said valve chamber and leading from said engine cylinder, valve means for alternately interrupting and permitting flow of fluid through said pressure transfer passageway and through said valve chamber from said cylinder to said exhaust passage, said valve means including a valve piston shiftably disposed in said valve chamber, and pilot valve means extending coaxially with respect to said valve piston and said engine piston, said pilot valve means having a passageway for alternately admitting fluid to and exhausting fluid from said valve chamber at one end of said valve piston upon reciprocation of said pilot valve means,

and abutment means at opposite ends of said engine cylinder for engaging and shifting said pilot valve means as said engine piston approaches the opposite ends of said cylinder.

20. A fluid pressure operated engine for reciprocating well pumps, comprising an engine cylinder, a differential end area piston shiftably disposed in said cylinder, said cylinder having an inlet port for the admission of power fluid into the cylinder between the smaller end of said piston and one end of the cylinder, said piston having a valve chamber therein, a pressure transfer passageway for establishing communication between said valve chamber and said cylinder at opposite ends of said piston, and an exhaust passage communicating with said valve chamber and leading from said engine cylinder, valve means for alternately interrupting and permitting flow of fluid through said pressure transfer passageway and through said valve chamber from said cylinder at the larger end of said piston to said exhaust passage, said valve means including a valve piston shiftably disposed in said valve chamber, and pilot valve means extending coaxially with respect to said valve piston and said engine piston, said pilot valve means having a passageway for alternately admitting fluid to and exhausting fluid from said valve chamber at one end of said valve piston upon reciprocation of said pilot valve means, and abutment means at opposite ends of said engine cylinder for engaging and shifting said pilot valve means as said engine piston approaches the opposite ends of said cylinder.

21. A fluid pressure operated engine for reciprocating well pumps, comprising an engine cylinder, a differential end area piston shiftably disposed in said cylinder, said cylinder having an inlet port for the admission of power fluid into the cylinder between the smaller end of said piston and one end of the cylinder, said piston having a

valve chamber therein, a pressure transfer passageway for establishing communicating between said valve chamber and said cylinder at opposite ends of said piston, and an exhaust passage communicating with said valve chamber and leading from said engine cylinder, valve means for alternately interrupting and permitting flow of fluid through said pressure transfer passageway and through said valve chamber from said cylinder at the larger end of said piston to said exhaust passage, said valve means including a valve piston shiftably disposed in said valve chamber, said valve piston having a head thereon provided with axially spaced opposed seating surfaces, axially spaced seats for said valve head, said pressure transfer passageway passing between said seats, and pilot valve means extending coaxially with respect to said valve piston and said engine piston, said pilot valve means having a passageway for alternately admitting fluid to and exhausting fluid from said valve chamber at one end of said valve piston upon reciprocation of said pilot valve means to effect alternate engagement of said seating surfaces on said valve head with said seats, and abutment means at opposite ends of said engine cylinder for engaging and shifting said pilot valve means as said engine piston approaches the opposite ends of said cylinder.

References Cited in the file of this patent

UNITED STATES PATENTS

437,806	Weatherhead	Oct. 7, 1890
585,083	Cook	June 22, 1897
825,950	Weir	July 17, 1906
2,134,174	Coberly	Oct. 25, 1938
2,631,541	Dempsey	Mar. 17, 1953
2,631,572	Dempsey	Mar. 17, 1953
2,751,889	Mohler	June 26, 1956